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(54) Projection lens and projection television system using the same.

(57) A projection lens for projecting images displayed on an image display device having angle-of-view dependency has high image focusing characteristics corresponding to high definition images, wide field angle, and telecentric characteristics. In addition, a projection television system using the same can be minimized in its size.

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Projection Lens and Projection Television System Using the Same

The present invention relates to a projection television system in which images formed, by means of electric signals as a result of changes of transmittance and reflectivity of the light, on an image display element are magnifyingly projected on a screen, and to a projection lens preferable to be used therein.

There has been a projection television system as the display devices with large image planes. The CRT

5 type projection television systems in which images of high brightness on the CRT are projected on the screen by means of the projection lens have been already used practically. On the other hand, a liquid crystal type projection television system in which images on a liquid crystal display element forming the images by changing transmittance and reflectivity of the light by means of video signals are magnifyingly projected on a screen starts being developed.

10 In case of projecting images on the liquid crystal display element, there occur problems, which are free from the CRT projection, as described below:

(1) Considering the angle-of-view dependency of the liquid crystal display element, a bundle of rays radiated in a specific range of angle toward the liquid crystal display element has to be utilized as a projection bundle of rays in order to project the images, which are formed on the liquid crystal display 15 element according to the video signals, on the screen with high contrast. Therefore, the projection lens are required to have telecentric characteristics that off-axis principal rays become vertical to the liquid crystal display element.

(2) The liquid crystal display element is driven by matrix electrodes, so that it is difficult to electrically compensate picture distortion of the projected images not like the projection system using the CRT devices.

20 Accordingly, the distortion aberration of the projection lens must be as small as possible.

These problems generally become a large obstacle to realize the wide picture angle of the projection lens which is necessary to minimize the size of the projection television system. These problems are not only against the liquid crystal display element but also against other image display elements which forms the images as a result of changes of transmittance and reflectivity of the light by means of video signals 25 using birefringence or rotatory polarization characteristics such as electric optical crystal and PLZT or the like having angle-of-view dependency.

An object of the present invention is to provide a projection television system with high performance and a lens preferable to be used therein having low distortion aberration and capability to project the images on an image display element having angle-of-view dependency forming the images as changes of 30 transmittance and reflectivity of the light by means of the electric signals in order to solve the above problems which occur due to the difference from the image projection of the CRT in case of projecting the images on the image display element having the angle-of-view dependency.

In order to achieve the above object, the projection television system of the present invention comprises: a light source; an image display element having angle-of-view dependency forming images as 35 changes of transmittance or reflectivity by means of image electric signals; a projection lens magnifyingly projecting a bundle of image rays achieved by transmitting the rays through said image display element or by reflecting the rays against said image display element, wherein said projection lens is provided so as to make off-axis principal rays substantially vertical to said image display element and has predetermined telecentric characteristics in order to obtain projection images with high contrast. It is desirable for the 40 projection lens to have a wide field angle particularly in order to achieve a compact transmission type projection television system. Accordingly, the projection lens has a constitution that an inverted telephoto type front lens group and a rear lens group having a front focal point nearby an exit pupil of said front lens group are provided.

According to the above constitution, the wide field angle can be achieved because the front group is 45 made of the inverted telephoto type lens, and the telecentric characteristics can be obtained by arranging the rear lens group having a front focal point nearby the exit pupil of said front lens group, so that the images on the image display element having angle-of-view characteristics can be magnifyingly projected on the screen with high contrast.

As described above, according to the present invention, an excellent image with high contrast can be 50 displayed, especially, a transmission type projection television system corresponding to the high definition of the images can be realized, and it is of great value in industry.

Fig. 1 is constitutional view showing constitution of a projection lens of a first embodiment.

Figs. 2 (a), (b), and (c) to 11 (a), (b), and (c) are graphs of characteristics of spherical aberration, astigmatism aberration, and distortion aberration of the first to tenth embodiments.

Fig. 12 is a constitutional diagram of a transmission type projection television set using a light source.

a reflection type liquid crystal element as an image display element having angle-of-view dependency, and a projection lens having telecentric characteristics.

The present invention is now described hereinafter referring to the drawings.

Fig. 1 is a view showing a schematic constitution of a projection television system, in which projection lens of a first embodiment of the present invention is used, using reflection type liquid crystal display element as an image display element having angle-of-view dependency. In Fig. 1, projection lens 3 constituted of a front lens group 1 and a rear lens group 2 having a front focal point nearby an exit pupil of said front lens group 3, polarizing beam splitter 4, a reflection type liquid crystal display element 5 are shown respectively. Light rays radiated from a light source 9 through an upper portion of the polarizing beam splitter 4 is refracted toward the reflection type liquid crystal display element 5 by means of the polarizing beam splitter 4, and goes into this reflection type liquid crystal display element 5. The light intensity-modulated according to images on the reflection type liquid crystal display element 5, then go through the polarizing beam splitter 4 and magnifyingly project the images on the reflection type liquid crystal display element 5 on a screen by means of the projection lens 3.

The projection lens 3 includes the front lens group 1 and the rear lens group 2 which are constituted by 7 pieces and 3 pieces of lens respectively. Namely, starting from the screen side, a first lens is a positive lens, a second lens is a negative meniscus lens having its convex surface facing the screen side, a third lens is a negative meniscus having its convex surface facing the screen side, a fourth lens is a bi-convex lens, a fifth lens is a negative meniscus lens including a comented surface and having its convex surface facing the screen surface, a sixth lens is a positive meniscus lens having its concave surface facing the screen side, a seventh lens is a bi-convex lens, an eight lens is a bi-concave lens, a ninth lens is a positive lens, and a tenth lens is a bi-convex lens. As described above, the first to seventh lens are the front lens group 1 of the inverted telephoto type lens constitution, and the eighth to tenth lens are the rear lens group 2 having the front focal point nearby the exit pupil of said front lens group 1. By means of this constitution, realized are the telecentric characteristics which are a required conditions for projecting the images on the reflection type liquid crystal display element with high contrast, and the aberrations such as the distortion aberration are compensated excellently.

In order to achieve these, it is desirable to meet a following condition.

$$0.8 < f_{1,7}/f < 1.4 \quad (1)$$

f : a total focal length of the entire system

$f_{1,7}$: a total focal length of the first to seventh lens

The condition (1) defines power distribution of the front lens group toward the entire system. It becomes difficult to meet a predetermined back focus when it goes beyond a lower limit. When it goes beyond an upper limit, the ear lens group has to have excessively large power, so that it becomes difficult to compensate the aberrations, especially the distortion and coma aberrations while keeping the telecentric characteristics.

More desirably, its characteristics improve more by meeting a condition below.

$$0.5 < d_{15}/f < 0.9 \quad (2)$$

f : a total focal length of the entire system

d_{15} : a distance between surfaces of the seventh and eighth lens

The condition (2) defines the distance between the surfaces of the front and rear lens groups 1 and 2. When it goes beyond a lower limit, the power of each lens becomes large in order to maintain the telecentric characteristics, and for the purpose of realizing the telecentric characteristics a symmetric property of the power is destroyed to an even greater extent while the power is originally in an asymmetric arrangement, so that it becomes difficult especially to compensate a lateral chromatic aberration. When it goes beyond an upper limit, it is easier to achieve the telecentric characteristics, but it becomes difficult to meet a predetermined back focus.

It is much more desirable to meet following conditions, and thus its characteristics improve even more.

$$d_{17}/l < 0.3 \quad (3)$$

$$-1.5 < f_8/f_{9,10} < -1.2 \quad (4)$$

f : a total focal length of the entire system

d_{17} : a distance between surfaces of the eighth and ninth lens

f_8 : a focal length of the eighth lens

$f_{9,10}$: a total focal length of the ninth and tenth lens

The conditions (3) and (4) relate particularly to the characteristics of the eighth to tenth lens, namely of the rear lens group 2. When it goes beyond an upper limit of the condition (3), effective diameters of the ninth and tenth lens become large, so that a problem over a required cost comes about. When it goes beyond a lower limit of the condition (4), a Petzval's sum becomes large, so that it becomes difficult to

compensate curvature of field. When it goes beyond an upper limit of the condition (4), the distortion aberration come to occur easily, so that it becomes difficult to compensate especially circumferences of image angles. In addition, it becomes difficult to compensate outer comas.

To introduce aspheric surface increases degree of freedom on aberration compensation and can realize more excellent image forming characteristics. In the projection lens of the present invention, the compensation of the distortion aberration in particular improves by introducing an aspheric surface into at least one of the first, second, eighth, ninth and tenth lenses. In addition, the aspheric surface can be easily formed, a manufacturing cost can decrease, and the lens can have lighter weight by forming the lens group having large diameters, such as the first and second lens, using plastics.

Each embodiment of the projection lens of the present invention is shown below. In each embodiment, r_1, r_2, \dots represent a radius of curvature of each surface starting from the screen side, d_1, d_2, \dots represent a distance between each of said surfaces, n_1, n_2, \dots represent a refractive index at an e-line of each lens, v_1, v_2, \dots represent an Abbe's number corresponding to the e-line of each of the above lens, surfaces represented by * are the aspheric surfaces. If Z is supposed a displacement amount from a vertex of a lens at a position away from an optical axis of the lens in a radius distance Y of an opening, it can be expressed as

$$Z = \frac{Y^2 / r}{1 + \sqrt{1 - (K+1) \cdot (Y/r)^2}} + AD \cdot Y^4 + AE \cdot Y^6 + AF \cdot Y^8 + AG \cdot Y^{10}$$

AD, AE, AF, and AG are aspherical coefficients, and K is a conical constant.

First embodiment

$f = 49.86$

Aperture ratio 1:2.8

Projection magnification 16.89

$\omega = 36.2^\circ$

$f_{1,7}/f = 1.08$

$d_{1,5}/f = 0.72$

$d_{1,7}/f = 0.12$

$f_8/f_{9,10} = -1.42$

$$r_1 = 136.783 \quad d_1 = 8.10 \quad n_1 = 1.51825 \quad v_1 = 63.8$$

$$r_2 = 961.173 \quad d_2 = 5.18$$

$$r_3 = 69.975 \quad d_3 = 6.00 \quad n_2 = 1.51825 \quad v_2 = 63.8$$

$$r_4 = 27.036 \quad d_4 = 8.97$$

$r_5 = 121.495$ $d_5 = 2.21$ $n_5 = 1.52555$ $\nu_5 = 50.5$

$^5 r_6 = 29.715$ $d_6 = 18.76$

$^{10} r_7 = 74.902$ $d_7 = 17.33$ $n_7 = 1.85503$ $\nu_7 = 23.7$

$r_8 = -372.104$ $d_8 = 6.68$

$^{15} r_9 = 271.686$ $d_9 = 17.77$ $n_9 = 1.79013$ $\nu_9 = 43.9$

$r_{10} = -25.786$ $d_{10} = 2.00$ $n_{10} = 1.76169$ $\nu_{10} = 27.3$

$^{20} r_{11} = 74.081$ $d_{11} = 4.62$

$^{25} r_{12} = -81.511$ $d_{12} = 4.50$ $n_{12} = 1.77622$ $\nu_{12} = 49.4$

$r_{13} = -43.199$ $d_{13} = 1.49$

$^{30} r_{14} = 204.097$ $d_{14} = 4.11$ $n_{14} = 1.79196$ $\nu_{14} = 47.1$

$r_{15} = -122.218$ $d_{15} = 35.89$

$^{35} r_{16} = -68.864$ $d_{16} = 2.66$ $n_{16} = 1.61075$ $\nu_{16} = 40.0$

$^{40} r_{17} = 275.832$ $d_{17} = 6.11$

$r_{18} = -1075.96$ $d_{18} = 10.52$ $n_{18} = 1.68083$ $\nu_{18} = 55.1$

$^{45} r_{19} = -88.713$ $d_{19} = 0.25$

$$r_{20} = 128.275 \quad d_{20} = 10.01 \quad n_{11} = 1.7762 \quad v_{11} = 49.4$$

$$r_{21} = -276.533 \quad d_{21} = 4.70$$

$$r_{22} = 0.000 \quad d_{22} = 41.10 \quad n_{12} = 1.51825 \quad v_{12} = 63.8$$

$$r_{23} = 0.000$$

Second embodiment

$$f = 49.82$$

Aperture ratio 1:2.8.

Projection magnification 16.94

$$\omega = 36.2^\circ$$

$$F_{1,7}/f = 1.05$$

$$d_{1,5}/f = 0.74$$

$$d_{1,7}/f = 0.16$$

$$f_8/f_{9,10} = -1.33$$

$$r_1 = 104.034 \quad d_1 = 11.00 \quad n_1 = 1.49384 \quad v_1 = 57.4 \quad *$$

$$r_2 = 466.780 \quad d_2 = 5.00 \quad *$$

$$r_3 = 73.295 \quad d_3 = 2.00 \quad n_2 = 1.49384 \quad v_2 = 57.4 \quad *$$

$$r_4 = 26.295 \quad d_4 = 11.00 \quad *$$

$$r_5 = 121.495 \quad d_5 = 2.21 \quad n_3 = 1.52555 \quad v_3 = 50.5$$

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$$r_6 = 29.715 \quad d_6 = 18.76$$

$$r_7 = 74.902 \quad d_7 = 17.33 \quad n_4 = 1.85503 \quad \nu_4 = 23.7$$

$$r_8 = -372.104 \quad d_8 = 6.68$$

$$r_9 = 271.686 \quad d_9 = 17.77 \quad n_5 = 1.79013 \quad \nu_5 = 43.9$$

$$r_{10} = -25.786 \quad d_{10} = 2.00 \quad n_6 = 1.76169 \quad \nu_6 = 27.3$$

$$r_{11} = 74.081 \quad d_{11} = 4.62$$

$$r_{12} = -81.511 \quad d_{12} = 4.50 \quad n_7 = 1.77622 \quad \nu_7 = 49.4$$

$$r_{13} = -43.199 \quad d_{13} = 1.49$$

$$r_{14} = 204.097 \quad d_{14} = 4.11 \quad n_8 = 1.79196 \quad \nu_8 = 47.1$$

$$r_{15} = -122.218 \quad d_{15} = 35.89$$

$$r_{16} = -62.109 \quad d_{16} = 2.66 \quad n_9 = 1.61075 \quad \nu_9 = 40.0$$

$$r_{17} = 213.114 \quad d_{17} = 7.80$$

$$r_{18} = 847.406 \quad d_{18} = 10.30 \quad n_{10} = 1.68083 \quad \nu_{10} = 55.1$$

$$r_{19} = -95.951 \quad d_{19} = 0.63$$

$$r_{20} = 121.641 \quad d_{20} = 10.45 \quad n_{11} = 1.77622 \quad \nu_{11} = 49.4$$

$$r_{21} = -255.505 \quad d_{21} = 4.50$$

$$r_{22} = 0.000 \quad d_{22} = 41.10 \quad n_{12} = 1.51825 \quad \nu_{12} = 63.8$$

$$r_{23} = 0.000$$

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First surface:

$$K = 0.655275$$

$$AD = 0.626082 \times 10^{-7}$$

$$AE = -0.144786 \times 10^{-10}$$

5 AF = $-0.109334 \times 10^{-14}$

Second surface:

$$K = 0.367907 \times 10^2$$

Third surface:

$$K = 0.440304$$

10 AD = 0.126898×10^{-7}

$$AE = 0.634832 \times 10^{-11}$$

$$AF = 0.928375 \times 10^{-14}$$

Fourth surface:

$$K = -0.241861 \times 10^{-1}$$

15 AD = 0.166124×10^{-6}

$$AE = 0.434466 \times 10^{-9}$$

$$AF = 0.561828 \times 10^{-12}$$

Third embodiment

20 f = 52.47

Aperture ratio 1:2.8

Projection magnification 17.19

$$\omega = 33.8^\circ$$

$$f_{17}, f = 1.09$$

25 d₁₅, f = 0.64

$$d_{17}, f = 0.12$$

$$f_8, f_{9,10} = -1.31$$

30

$$r_1 = 148.519 \quad d_1 = 8.40 \quad n_1 = 1.51825 \quad \nu_1 = 63.8 \quad *$$

$$r_2 = -6939.731 \quad d_2 = 5.18$$

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$$r_3 = 49.137 \quad d_3 = 6.00 \quad n_2 = 1.51825 \quad \nu_2 = 63.8$$

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$$r_4 = 29.177 \quad d_4 = 9.37 \quad * \quad$$

$$r_5 = 608.860 \quad d_5 = 2.21 \quad n_3 = 1.52555 \quad \nu_3 = 50.5$$

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$$r_6 = 28.525 \quad d_6 = 18.76$$

$$r_7 = 74.902 \quad d_7 = 17.33 \quad n_4 = 1.85503 \quad \nu_4 = 23.7$$

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$r_0 = -372.104 \quad d_0 = 6.68$
 5 $r_0 = 271.686 \quad d_0 = 17.77 \quad n_0 = 1.79013 \quad \nu_0 = 43.9$
 10 $r_{10} = -25.786 \quad d_{10} = 2.00 \quad n_0 = 1.76169 \quad \nu_0 = 27.3$
 15 $r_{11} = 74.081 \quad d_{11} = 4.62$
 20 $r_{12} = -81.511 \quad d_{12} = 4.50 \quad n_0 = 1.77622 \quad \nu_0 = 49.4$
 25 $r_{13} = -43.199 \quad d_{13} = 1.49$
 30 $r_{14} = 204.097 \quad d_{14} = 4.11 \quad n_0 = 1.79196 \quad \nu_0 = 47.1$
 35 $r_{15} = -122.218 \quad d_{15} = 33.60$
 40 $r_{16} = -49.674 \quad d_{16} = 2.66 \quad n_0 = 1.62059 \quad \nu_0 = 36.4$
 45 $r_{17} = 298.959 \quad d_{17} = 6.11$ *
 50 $r_{18} = -275.028 \quad d_{18} = 10.70 \quad n_{10} = 1.68083 \quad \nu_{10} = 55.1$ *
 55 $r_{19} = -56.037 \quad d_{19} = 0.25$
 60 $r_{20} = 341.327 \quad d_{20} = 11.05 \quad n_{11} = 1.77622 \quad \nu_{11} = 49.4$ *
 65 $r_{21} = -103.830 \quad d_{21} = 6.70$
 70 $r_{22} = 0.000 \quad d_{22} = 43.30 \quad n_{12} = 1.51825 \quad \nu_{12} = 63.8$
 75 $r_{23} = 0.000$

Aspheric coefficient

First surface:

$K = -0.2749912 \times 10^{-1}$

$AD = 0.2548179 \times 10^{-7}$

$AE = -0.2056712 \times 10^{-10}$

$AF = -0.4319405 \times 10^{-14}$

$AG = 0.8811238 \times 10^{-18}$

Fourth surface:

$K = 0.3668809 \times 10^{-1}$

$AD = 0.1536691 \times 10^{-6}$

$AE = -0.1142634 \times 10^{-10}$

$AF = 0.8573753 \times 10^{-12}$
 $AG = 0.2158643 \times 10^{-15}$
 Seventeenth surface:
 $K = 0.2637872 \times 10^2$
 5 $AD = 0.1858271 \times 10^{-6}$
 $AE = 0.1334531 \times 10^{-10}$
 $AF = 0.2612238 \times 10^{-13}$
 $AG = 0.9178511 \times 10^{-17}$
 Eighteenth surface:
 10 $K = 0.5903051 \times 10^1$
 $AD = -0.2472130 \times 10^{-6}$
 $AE = 0.1460313 \times 10^{-9}$
 $AF = 0.3400976 \times 10^{-13}$
 $AG = 0.3706282 \times 10^{-17}$
 15 Twentieth surface:
 $K = -0.9201606$
 $AD = -0.1022347 \times 10^{-6}$
 $AE = 0.7465995 \times 10^{-10}$
 $AF = 0.1567219 \times 10^{-13}$
 20 $AG = 0.1032802 \times 10^{-17}$

Fourth embodiment

$F = 49.94$
 Aperture ratio 1:2.8
 25 Projection magnification 18.09
 $\omega = 34.1^\circ$
 $f_{1,7}, f = 1.14$
 $d_{15}, f = 0.67$
 $d_{17}, f = 0.12$
 30 $f_8, f_{9,10} = -1.37$

$$r_1 = 146.163 \quad d_1 = 8.40 \quad n_1 = 1.51825 \quad v_1 = 63.8 \quad *$$

$$35 \quad r_2 = 0.000 \quad d_2 = 5.18$$

$$r_3 = 49.670 \quad d_3 = 6.00 \quad n_2 = 1.51825 \quad v_2 = 63.8$$

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$r_4 = 29.101 \quad d_4 = 9.39 \quad *$
 $5 \quad r_5 = 937.536 \quad d_5 = 2.21 \quad n_5 = 1.52555 \quad \nu_5 = 50.5$
 $r_6 = 28.141 \quad d_6 = 18.76$
 $10 \quad r_7 = 74.902 \quad d_7 = 17.33 \quad n_7 = 1.85503 \quad \nu_7 = 23.7$
 $r_8 = -372.104 \quad d_8 = 6.68$
 $15 \quad r_9 = 271.686 \quad d_9 = 17.77 \quad n_9 = 1.79013 \quad \nu_9 = 43.9$
 $20 \quad r_{10} = -25.786 \quad d_{10} = 2.00 \quad n_{10} = 1.76169 \quad \nu_{10} = 27.3$
 $r_{11} = 74.081 \quad d_{11} = 4.62$
 $25 \quad r_{12} = -81.511 \quad d_{12} = 4.50 \quad n_{12} = 1.77622 \quad \nu_{12} = 49.4$
 $r_{13} = -43.199 \quad d_{13} = 1.49$
 $30 \quad r_{14} = 204.097 \quad d_{14} = 4.11 \quad n_{14} = 1.79196 \quad \nu_{14} = 47.1$
 $r_{15} = -122.218 \quad d_{15} = 33.60$
 $r_{16} = -49.674 \quad d_{16} = 2.66 \quad n_{16} = 1.62059 \quad \nu_{16} = 36.4$
 $40 \quad r_{17} = 303.305 \quad d_{17} = 6.11 \quad *$
 $r_{18} = -310.381 \quad d_{18} = 10.70 \quad n_{18} = 1.68083 \quad \nu_{18} = 55.1 \quad *$
 45

$z_9 = -54.486$ $d_{1,9} = 0.25$

5 $z_0 = 275.356$ $d_{2,0} = 11.05$ $n_{1,1} = 1.77622$ $\nu_{1,1} = 49.4$ *

$z_1 = -108.456$ $d_{2,1} = 6.70$

10 $z_2 = 0.000$ $d_{2,2} = 43.30$ $n_{1,2} = 1.51825$ $\nu_{1,2} = 63.8$

$z_3 = 0.000$

15

Aspheric coefficient

First surface:

$$K = -0.2301050 \times 10^{-1}$$

$$AD = 0.2511178 \times 10^{-7}$$

20 $AE = -0.1943356 \times 10^{-10}$

$$AF = -0.3619595 \times 10^{-14}$$

$$AG = 0.8095271 \times 10^{-18}$$

Fourth surface:

$$K = 0.3295092 \times 10^{-1}$$

25 $AD = -0.4594244 \times 10^{-7}$

$$AE = 0.7461787 \times 10^{-10}$$

$$AF = 0.4135199 \times 10^{-12}$$

$$AG = -0.3071122 \times 10^{-15}$$

Seventeenth surface:

30 $K = 0.2504243 \times 10^2$

$$AD = 0.1782731 \times 10^{-6}$$

$$AE = -0.1529465 \times 10^{-11}$$

$$AF = 0.2164382 \times 10^{-13}$$

$$AG = -0.7725707 \times 10^{-17}$$

35 Eighteenth surface:

$$K = 0.1032711 \times 10^2$$

$$AD = -0.2772488 \times 10^{-6}$$

$$AE = 0.1544648 \times 10^{-9}$$

$$AF = 0.2193979 \times 10^{-13}$$

40 $AG = -0.1042978 \times 10^{-16}$

Twentieth surface:

$$K = -0.5525461 \times 10^1$$

$$AD = -0.1231838 \times 10^{-6}$$

$$AE = 0.8516421 \times 10^{-10}$$

45 $AF = 0.1510178 \times 10^{-13}$

$$AG = 0.1229936 \times 10^{-18}$$

Fifth embodiment

$$f = 50.00$$

Aperture ratio 1:2.8

50 Projection magnification 18.10

$$\omega = 34.0^\circ$$

$$f_{1,7}/f = 1.14$$

$$d_{1,5}/f = 0.67$$

$$d_{1,7}/f = 0.12$$

55 $f_8/f_{9,10} = -1.35$

r₁ = 139.093 d₁ = 8.40 n₁ = 1.51825 ν₁ = 63.8 *

5 r₂ = 1883.809 d₂ = 5.18

r₃ = 44.322 d₃ = 6.00 n₂ = 1.51825 ν₂ = 63.8

10 r₄ = 26.610 d₄ = 11.06

r₅ = 1031.968 d₅ = 2.21 n₃ = 1.52555 ν₃ = 50.5

15 r₆ = 28.804 d₆ = 18.76

r₇ = 74.902 d₇ = 17.33 n₄ = 1.85503 ν₄ = 23.7

20 r₈ = -372.104 d₈ = 6.68

r₉ = 271.686 d₉ = 17.77 n₅ = 1.79013 ν₅ = 43.9

r₁₀ = -25.786 d₁₀ = 2.00 n₆ = 1.76169 ν₆ = 27.3

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$r_{1,1} = 74.081$ $d_{1,1} = 4.62$

5 $r_{1,2} = -81.511$ $d_{1,2} = 4.50$ $n_7 = 1.77622$ $\nu_7 = 49.4$

10 $r_{1,3} = -43.199$ $d_{1,3} = 1.49$

15 $r_{1,4} = 204.097$ $d_{1,4} = 4.11$ $n_8 = 1.79196$ $\nu_8 = 47.1$

20 $r_{1,5} = -122.218$ $d_{1,5} = 33.60$

25 $r_{1,6} = -48.652$ $d_{1,6} = 2.66$ $n_9 = 1.62059$ $\nu_9 = 36.4$

30 $r_{1,7} = 293.965$ $d_{1,7} = 6.11$ *

35 $r_{1,8} = -406.452$ $d_{1,8} = 10.70$ $n_{10} = 1.68083$ $\nu_{10} = 55.1$ *

40 $r_{1,9} = -56.325$ $d_{1,9} = 0.25$

45 $r_{2,0} = 243.391$ $d_{2,0} = 11.05$ $n_{11} = 1.77622$ $\nu_{11} = 49.4$

50 $r_{2,1} = -112.964$ $d_{2,1} = 6.70$

55 $r_{2,2} = 0.000$ $d_{2,2} = 43.30$ $n_{12} = 1.51825$ $\nu_{12} = 63.8$

60 $r_{2,3} = 0.000$

65 Aspheric coefficient

First surface:

K = 0.3664325

AD = 0.4574458×10^{-7}

AE = $-0.3507965 \times 10^{-10}$

AF = $0.2388062 \times 10^{-14}$

AG = $0.2247566 \times 10^{-19}$

Seventeenth surface:

K = 0.1229070×10^2

AD = 0.9272514×10^{-7}

AE = $-0.3770400 \times 10^{-10}$

AF = $0.1428259 \times 10^{-12}$

AG = $0.5601794 \times 10^{-16}$

Eighteenth surface:

K = 0.2118076×10^2

AD = $-0.4127061 \times 10^{-6}$

AE = 0.2205876×10^{-9}

AF = $0.6059036 \times 10^{-13}$

AG = $0.6235547 \times 10^{-16}$

Sixth embodiment

 $F = 50.15$

Aperture ratio 1:2.8

Projection magnification 18.09

5 $\omega = 34.1$ $f_{17}/f = 1.15$ $d_{15}/f = 0.67$ $d_{17}/f = 0.12$ $f_8 f_9 f_{10} = -1.33$

10

$$r_1 = 138.102 \quad d_1 = 8.40 \quad n_1 = 1.51825 \quad \nu_1 = 63.8 \quad *$$

15

$$r_2 = 3278.162 \quad d_2 = 5.18$$

$$r_3 = 48.685 \quad d_3 = 6.00 \quad n_2 = 1.51825 \quad \nu_2 = 63.8$$

20

$$r_4 = 29.654 \quad d_4 = 11.06$$

$$r_5 = 1869.065 \quad d_5 = 2.21 \quad n_3 = 1.52555 \quad \nu_3 = 50.5$$

25

$$r_6 = 27.929 \quad d_6 = 18.76$$

30

$$r_7 = 74.902 \quad d_7 = 17.33 \quad n_4 = 1.85503 \quad \nu_4 = 23.7$$

$$r_8 = -372.104 \quad d_8 = 6.68$$

35

$$r_9 = 271.686 \quad d_9 = 17.77 \quad n_5 = 1.79013 \quad \nu_5 = 43.9$$

40

$$r_{10} = -25.786 \quad d_{10} = 2.00 \quad n_6 = 1.76169 \quad \nu_6 = 27.3$$

45

$$r_{1,1} = 74.081 \quad d_{1,1} = 4.62$$

$$5 \quad r_{1,2} = -81.511 \quad d_{1,2} = 4.50 \quad n_7 = 1.77622 \quad \nu_7 = 49.4$$

$$r_{1,3} = -43.199 \quad d_{1,3} = 1.49$$

$$10 \quad r_{1,4} = 204.097 \quad d_{1,4} = 4.11 \quad n_8 = 1.79196 \quad \nu_8 = 47.1$$

$$r_{1,5} = -122.218 \quad d_{1,5} = 33.60$$

$$15 \quad r_{1,6} = -45.791 \quad d_{1,6} = 2.66 \quad n_9 = 1.62059 \quad \nu_9 = 36.4$$

$$20 \quad r_{1,7} = 288.771 \quad d_{1,7} = 6.11 \quad *$$

$$r_{1,8} = -339.448 \quad d_{1,8} = 11.20 \quad n_{10} = 1.68083 \quad \nu_{10} = 55.1$$

$$25 \quad r_{1,9} = -52.879 \quad d_{1,9} = 0.25$$

$$r_{2,0} = 237.092 \quad d_{2,0} = 11.05 \quad n_{11} = 1.77622 \quad \nu_{11} = 49.4 \quad *$$

$$30 \quad r_{2,1} = -107.581 \quad d_{2,1} = 6.70$$

$$r_{2,2} = 0.000 \quad d_{2,2} = 43.30 \quad n_{12} = 1.51825 \quad \nu_{12} = 63.8$$

$$35 \quad r_{2,3} = 0.000$$

40 Aspheric coefficient

First surface:

$$K = -0.8676696$$

$$AD = 0.4922937 \times 10^{-7}$$

$$AE = -0.2681624 \times 10^{-10}$$

$$45 AF = 0.4039305 \times 10^{-14}$$

$$AG = -0.6315714 \times 10^{-18}$$

Seventeenth surface:

$$K = 0.1204351 \times 10^2$$

$$AD = 0.8134826 \times 10^{-7}$$

$$50 AE = 0.3285905 \times 10^{-11}$$

$$AF = -0.3382158 \times 10^{-13}$$

$$AG = 0.1685514 \times 10^{-16}$$

Twentieth surface:

$$K = -0.1760054 \times 10^2$$

$$55 AD = -0.2229407 \times 10^{-6}$$

$$AE = 0.8474120 \times 10^{-10}$$

$$AF = 0.3501296 \times 10^{-13}$$

$$AG = -0.6162020 \times 10^{-17}$$

Seventh embodiment

 $f = 49.98$

Aperture ratio 1:2.8

Projection magnification 18.09

5 $\omega = 34.2^\circ$ $f_{17} \cdot f = 1.16$ $d_{15} \cdot f = 0.67$ $d_{17} \cdot f = 0.12$ $f_3 \cdot f_{9,10} = -1.35$

10

$$r_1 = 97.304 \quad d_1 = 8.40 \quad n_1 = 1.51825 \quad \nu_1 = 63.8$$

15

$$r_2 = 419.135 \quad d_2 = 5.18$$

$$r_3 = 71.654 \quad d_3 = 6.00 \quad n_2 = 1.51825 \quad \nu_2 = 63.8$$

20

$$r_4 = 34.797 \quad d_4 = 7.04$$

$$r_5 = 373.100 \quad d_5 = 2.21 \quad n_3 = 1.52555 \quad \nu_3 = 50.5$$

25

$$r_6 = 27.138 \quad d_6 = 18.76$$

30

$$r_7 = 74.902 \quad d_7 = 17.33 \quad n_4 = 1.85503 \quad \nu_4 = 23.7$$

$$r_8 = -372.104 \quad d_8 = 6.68$$

35

$$r_9 = 271.686 \quad d_9 = 17.77 \quad n_5 = 1.79013 \quad \nu_5 = 43.9$$

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EP 0 385 698 A2

$r_{1,0} = -25.786 \quad d_{1,0} = 2.00 \quad n_s = 1.76169 \quad \nu_s = 27.3$

5 $r_{1,1} = 74.081 \quad d_{1,1} = 4.62$

$r_{1,2} = -81.511 \quad d_{1,2} = 4.50 \quad n_s = 1.77622 \quad \nu_s = 49.4$

10 $r_{1,3} = -43.199 \quad d_{1,3} = 1.49$

$r_{1,4} = 204.097 \quad d_{1,4} = 4.11 \quad n_s = 1.79196 \quad \nu_s = 47.1$

15 $r_{1,5} = -122.218 \quad d_{1,5} = 33.60$

20 $r_{1,6} = -47.158 \quad d_{1,6} = 2.66 \quad n_s = 1.62059 \quad \nu_s = 36.4$

$r_{1,7} = 234.453 \quad d_{1,7} = 6.11 \quad *$

25 $r_{1,8} = -282.754 \quad d_{1,8} = 10.70 \quad n_{1,0} = 1.68083 \quad \nu_{1,0} = 55.1 \quad *$

30 $r_{1,9} = -50.375 \quad d_{1,9} = 0.25$

$r_{2,0} = 387.424 \quad d_{2,0} = 11.05 \quad n_{1,1} = 1.77622 \quad \nu_{1,1} = 49.4 \quad *$

35 $r_{2,1} = -89.653 \quad d_{2,1} = 6.70$

$r_{2,2} = 0.000 \quad d_{2,2} = 43.30 \quad n_{1,2} = 1.51825 \quad \nu_{1,2} = 63.8$

40 $r_{2,3} = 0.000$

Aspheric coefficient

45 Seventeenth surface:

$$K = 0.3064228 \times 10^2$$

$$AD = 0.3424168 \times 10^{-6}$$

$$AE = 0.1524318 \times 10^{-11}$$

$$AF = 0.2578158 \times 10^{-14}$$

$$AG = -0.1657459 \times 10^{-16}$$

50 Eighteenth surface:

$$K = -0.1540423 \times 10^2$$

$$AD = -0.1423166 \times 10^{-6}$$

$$AE = 0.2421751 \times 10^{-9}$$

$$AF = 0.9010286 \times 10^{-13}$$

$$AG = 0.6174771 \times 10^{-16}$$

Twentieth surface:

$$K = -0.1023903 \times 10^3$$

$AD = -0.2301108 \times 10^{-6}$
 $AE = 0.1076672 \times 10^{-9}$
 $AF = -0.1514403 \times 10^{-14}$
 $AG = -0.3385086 \times 10^{-17}$

5 Eighth embodiment
 $f = 50.09$
 Aperture ratio 1:2.8
 Projection magnification 18.09
 $\omega = 34.1^\circ$

10 $f_1, f_7 = 1.13$
 $d_{1,5} f = 0.67$
 $d_{1,7} f = 0.12$
 $f_6 \cdot f_{9,10} = -1.34$

15 $r_1 = 100.392$ $d_1 = 8.40$ $n_1 = 1.51825$ $\nu_1 = 63.8$ *

20 $r_2 = 203.275$ $d_2 = 5.18$

25 $r_3 = 39.627$ $d_3 = 6.00$ $n_2 = 1.51825$ $\nu_2 = 63.8$

30 $r_4 = 24.889$ $d_4 = 12.47$

35 $r_5 = 566.809$ $d_5 = 2.21$ $n_3 = 1.52555$ $\nu_3 = 50.5$

40 $r_6 = 29.209$ $d_6 = 18.76$

45 $r_7 = 74.902$ $d_7 = 17.33$ $n_4 = 1.85503$ $\nu_4 = 23.7$

50 $r_8 = -372.104$ $d_8 = 6.68$

55 $r_9 = 271.686$ $d_9 = 17.77$ $n_5 = 1.79013$ $\nu_5 = 43.9$

40 $r_{1,0} = -25.786 \quad d_{1,0} = 2.00 \quad n_6 = 1.76169 \quad \nu_6 = 27.3$

5 $r_{1,1} = 74.081 \quad d_{1,1} = 4.62$

10 $r_{1,2} = -81.511 \quad d_{1,2} = 4.50 \quad n_7 = 1.77622 \quad \nu_7 = 49.4$

15 $r_{1,3} = -43.199 \quad d_{1,3} = 1.49$

20 $r_{1,4} = 204.097 \quad d_{1,4} = 4.11 \quad n_8 = 1.79196 \quad \nu_8 = 47.1$

25 $r_{1,5} = -122.218 \quad d_{1,5} = 35.89$

30 $r_{1,6} = -49.808 \quad d_{1,6} = 2.66 \quad n_9 = 1.62059 \quad \nu_9 = 36.4$

35 $r_{1,7} = 275.553 \quad d_{1,7} = 6.11 \quad *$

40 $r_{1,8} = -519.026 \quad d_{1,8} = 10.70 \quad n_{1,0} = 1.68083 \quad \nu_{1,0} = 55.1$

45 $r_{1,9} = -60.159 \quad d_{1,9} = 0.25$

50 $r_{2,0} = 250.814 \quad d_{2,0} = 11.05 \quad n_{1,1} = 1.77622 \quad \nu_{1,1} = 49.4$

55 $r_{2,1} = -108.683 \quad d_{2,1} = 6.70$

60 $r_{2,2} = 0.000 \quad d_{2,2} = 43.30 \quad n_{1,2} = 1.51825 \quad \nu_{1,2} = 63.8$

65 $r_{2,3} = 0.000$

Aspheric coefficient

First surface:

45 $K = 0.9525501$

$AD = 0.2216984 \times 10^{-6}$

$AE = -0.4500812 \times 10^{-10}$

$AF = 0.1270679 \times 10^{-13}$

$AG = -0.2481052 \times 10^{-17}$

50 Seventeenth surface:

$K = 0.3154613 \times 10^2$

$AD = 0.5889586 \times 10^{-6}$

$AE = -0.5654111 \times 10^{-13}$

$AF = 0.5498361 \times 10^{-13}$

$AG = 0.2775640 \times 10^{-16}$

Ninth embodiment

$f = 49.91$

Aperture ratio 1:2.8

Projection magnification 18.07

 $\omega = 34.2^\circ$ $f_1 : f = 1.13$ 5 $d_{15} : f = 0.67$ $d_{17} : f = 0.12$ $f_8 : f_{9,10} = -1.39$ 10 $r_1 = 92.116 \quad d_1 = 8.40 \quad n_1 = 1.51825 \quad v_1 = 63.8 \quad *$ $r_2 = 256.167 \quad d_2 = 5.18$ 15 $r_3 = 60.670 \quad d_3 = 6.00 \quad n_2 = 1.51825 \quad v_2 = 63.8$ $r_4 = 29.056 \quad d_4 = 8.80$ 20 $r_5 = 222.628 \quad d_5 = 2.21 \quad n_3 = 1.52555 \quad v_3 = 50.5$ 25 $r_6 = 28.187 \quad d_6 = 18.76$ $r_7 = 74.902 \quad d_7 = 17.33 \quad n_4 = 1.85503 \quad v_4 = 23.7$ 30 $r_8 = -372.104 \quad d_8 = 6.68$ $r_9 = 271.686 \quad d_9 = 17.77 \quad n_5 = 1.79013 \quad v_5 = 43.9$ 35 $r_{10} = -25.786 \quad d_{10} = 2.00 \quad n_6 = 1.76169 \quad v_6 = 27.3$ $r_{11} = 74.081 \quad d_{11} = 4.62$ 40 $r_{12} = -81.511 \quad d_{12} = 4.50 \quad n_7 = 1.77622 \quad v_7 = 49.4$ 45 $r_{13} = -43.199 \quad d_{13} = 1.49$ $r_{14} = 204.097 \quad d_{14} = 4.11 \quad n_8 = 1.79196 \quad v_8 = 47.1$ 50 $r_{15} = -122.218 \quad d_{15} = 35.89$

EP O 385 698 A2

5 $r_{1,6} = -55.629$ $d_{1,6} = 2.66$ $n_6 = 1.62059$ $\nu_6 = 36.4$

10 $r_{1,7} = 243.662$ $d_{1,7} = 6.11$

15 $r_{1,8} = -319.338$ $d_{1,8} = 10.70$ $n_{1,8} = 1.68083$ $\nu_{1,8} = 55.1 *$

20 $r_{1,9} = -61.756$ $d_{1,9} = 0.25$

25 $r_{2,0} = 302.607$ $d_{2,0} = 11.05$ $n_{1,1} = 1.77622$ $\nu_{1,1} = 49.4$

30 $r_{2,1} = -96.776$ $d_{2,1} = 6.70$

35 $r_{2,2} = 0.000$ $d_{2,2} = 43.30$ $n_{1,2} = 1.51825$ $\nu_{1,2} = 63.8$

40 $r_{2,3} = 0.000$

45 Aspheric coefficient

First surface:

$K = 0.3399632$

$AD = 0.7523389 \times 10^{-7}$

$AE = -0.6005325 \times 10^{-10}$

50 $AF = 0.2647887 \times 10^{-13}$

$AG = -0.5935675 \times 10^{-17}$

55 Eighteenth surface:

$K = 0.2756654 \times 10^2$

$AD = -0.7554289 \times 10^{-6}$

60 $AE = 0.3478933 \times 10^{-9}$

$AF = -0.7082334 \times 10^{-13}$

$AG = 0.2544740 \times 10^{-16}$

65 Tenth embodiment

$f = 50.04$

70 Aperture ratio 1:2.8

Projection magnification 18.10

$\omega = 34.2^\circ$

$f_{1,7}/f = 1.14$

$d_{15}/f = 0.67$

80 $d_{17}/f = 0.12$

$f_8/f_{9,10} = -1.31$

1 r₁ = 114.457 d₁ = 8.40 n₁ = 1.51825 v₁ = 63.8 *

5 r₂ = 483.920 d₂ = 5.18

r₃ = 48.101 d₃ = 6.00 n₂ = 1.51825 v₂ = 63.8

10 r₄ = 28.146 d₄ = 9.91

r₅ = 575.308 d₅ = 2.21 n₃ = 1.52555 v₃ = 50.5

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$$r_6 = 28.386 \quad d_6 = 18.76$$

5 $r_7 = 74.902 \quad d_7 = 17.33 \quad n_4 = 1.85503 \quad \nu_4 = 23.7$

$$r_8 = -372.104 \quad d_8 = 6.68$$

10 $r_9 = 271.686 \quad d_9 = 17.77 \quad n_5 = 1.79013 \quad \nu_5 = 43.9$

$$r_{10} = -25.786 \quad d_{10} = 2.00 \quad n_6 = 1.76169 \quad \nu_6 = 27.3$$

15 $r_{11} = 74.081 \quad d_{11} = 4.62$

20 $r_{12} = -81.511 \quad d_{12} = 4.50 \quad n_7 = 1.77622 \quad \nu_7 = 49.4$

$$r_{13} = -43.199 \quad d_{13} = 1.49$$

25 $r_{14} = 204.097 \quad d_{14} = 4.11 \quad n_8 = 1.79196 \quad \nu_8 = 47.1$

$$r_{15} = -122.218 \quad d_{15} = 33.60$$

30 $r_{16} = -46.081 \quad d_{16} = 2.66 \quad n_9 = 1.62059 \quad \nu_9 = 36.4$

$$r_{17} = 228.576 \quad d_{17} = 6.11$$

35 $r_{18} = -509.475 \quad d_{18} = 10.70 \quad n_{10} = 1.68083 \quad \nu_{10} = 55.1$

$$r_{19} = -54.905 \quad d_{19} = 0.25$$

40 $r_{20} = 238.750 \quad d_{20} = 11.05 \quad n_{11} = 1.77622 \quad \nu_{11} = 49.4 \quad *$

45

$$r_{21} = -103.160 \quad d_{21} = 6.70$$

50 $r_{22} = 0.000 \quad d_{22} = 43.30 \quad n_{12} = 1.51825 \quad \nu_{12} = 63.8$

55 $r_{23} = 0.000$

K = 0.7070278
AD = 0.1345127×10^{-7}
AE = $-0.3754727 \times 10^{-10}$
AF = $0.6046046 \times 10^{-14}$
5 AG = $-0.1657469 \times 10^{-17}$
Twentieth surface:
K = -0.1850460×10^2
AD = $-0.2560358 \times 10^{-6}$
AE = $0.6946116 \times 10^{-10}$
10 AF = $0.3196880 \times 10^{-13}$
AG = $-0.5231959 \times 10^{-17}$

In the above embodiment, the radius of curvature values 0.000 represent flat surfaces. Figs. 2 (a), (b), (c) to 11 (a), (b), (c) are characteristic graphs of the spheric aberrations, astigmatism aberrations, and distortion aberrations of the first to tenth embodiments. As it is obvious in the characteristic graphs, each of 15 the aberration is fairly compensated, and the high quality characteristics of images are realized.

In each of the above embodiments, the reflection type liquid crystal element is used as the image display element, it is not limited to the reflection type liquid crystal element, and can be replaced, as described earlier, by the image display devices, which form images as changes of transmittance and reflectivity by means of electric signals making use of birefringence and rotatory polarization characteristics 20 electro optical crystal, PLZT, and so on.

Fig. 12 is a schematic constitutional view of the transmission type projection television system using the light source 9, the reflection type liquid crystal element 5 as the image display device having the angle-of-view dependency, and the projection lens 3, which has the telecentric characteristics, of the present invention. A bundle of image rays is magnifyingly projected on the screen 6 through the polarizing beam 25 splitter 4 by means of the projection lens 3 of the present invention. A mirror 8 is used for bending a route of the projection light for the purpose of minimizing the size of the housing of the transmission type projection television system. The reflection type liquid crystal display element itself is smaller than the conventional CRT devices forming images, and the projection lens has the high quality characteristics of images and the characteristics of wide field angle, so that the unique transmission type projection television 30 having both the high quality characteristics of images and the minimized size can be realized.

Claims

- 35 1. A projection lens having light coming from a light source into an image display device forming images as changes of transmittance or reflectivity by means of electric signals, and projecting the transmission or reflection light on the screen, wherein said projection lens comprises an inverted telephoto type front lens group at a screen side and a rear lens group having a front focal point nearby an exit pupil of said front lens group, and has telecentric characteristics.
- 40 2. A projection lens according to claim 1, wherein the front lens group including 7 pieces of lens, the rear lens group including 3 pieces of lens, and said projection lens meets the following conditions:
 $0.8 < f_{1,7}/f < 1.4$
 $f_{1,7}$: a total focal length of the front lens group, namely the first to seventh lens
 f : a total focal length of the entire system
- 45 3. A projection lens according to claim 1, wherein the front lens group including 7 pieces of lens, the rear lens group including 3 pieces of lens, and starting from the screen side, a first lens is a positive lens, a second lens is a negative meniscus lens having its convex surface facing the screen side, a third lens is a negative meniscus lens having its convex surface facing the screen side, a fourth lens is a bi-convex lens, a fifth lens is a negative meniscus lens including a cemented surface and having its convex surface facing the 50 screen surface, a sixth lens is a positive meniscus lens having its concave surface facing the screen side, a seventh lens is a bi-convex lens, an eighth lens is a bi-concave lens, a ninth lens is a positive lens, and a tenth lens is a bi-convex lens.
4. A projection lens according to claim 2 meeting the following conditions:
 $0.5 < d_{15}/f < 0.9$
55 when a distance between surfaces of the front and rear lens groups is given as d_{15} , and a total focal length of the entire system is given as f .
5. A projection lens according to claim 3 meeting the following conditions:
 $d_{17}/f < 0.3$

$$-1.5 < f_8 \cdot f_{9,10} < -1.2$$

when it is given that a distance between surfaces of the eighth and ninth is d_{17} , a focal length of the eighth lens is f_8 , a total focal length of the ninth and tenth lens is $f_{9,10}$, and a total focal length of the entire system is f .

5 6. A projection lens according to claim 3, satisfying substantially the following conditions:

$$f = 49.86$$

Aperture ratio 1:2.8

Projection magnification 16.89

$$\omega = 36.2^\circ$$

$$10 f_{1,7} \cdot f = 1.08$$

$$d_{1,5} \cdot f = 0.72$$

$$d_{1,7} \cdot f = 0.12$$

$$f_8 \cdot f_{9,10} = -1.42$$

$$15 r_1 = 136.783 \quad d_1 = 8.10 \quad n_1 = 1.51825 \quad v_1 = 63.8$$

$$r_2 = 961.173 \quad d_2 = 5.18$$

$$20 r_3 = 69.975 \quad d_3 = 6.00 \quad n_2 = 1.51825 \quad v_2 = 63.8$$

$$25 r_4 = 27.036 \quad d_4 = 8.97$$

$$r_5 = 121.495 \quad d_5 = 2.21 \quad n_3 = 1.52555 \quad v_3 = 50.5$$

$$30 r_6 = 29.715 \quad d_6 = 18.76$$

$$35 r_7 = 74.902 \quad d_7 = 17.33 \quad n_4 = 1.85503 \quad v_4 = 23.7$$

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$$r_8 = -372.104 \quad d_8 = 6.68$$

$$5 \quad r_9 = 271.686 \quad d_9 = 17.77 \quad n_5 = 1.79013 \quad v_5 = 43.9$$

$$r_{10} = -25.786 \quad d_{10} = 2.00 \quad n_6 = 1.76169 \quad v_6 = 27.3$$

$$10 \quad r_{11} = 74.081 \quad d_{11} = 4.62$$

$$15 \quad r_{12} = -81.511 \quad d_{12} = 4.50 \quad n_7 = 1.77622 \quad v_7 = 49.4$$

$$r_{13} = -43.199 \quad d_{13} = 1.49$$

$$20 \quad r_{14} = 204.097 \quad d_{14} = 4.11 \quad n_8 = 1.79196 \quad v_8 = 47.1$$

$$r_{15} = -122.218 \quad d_{15} = 35.89$$

$$25 \quad r_{16} = -68.864 \quad d_{16} = 2.66 \quad n_9 = 1.61075 \quad v_9 = 40.0$$

$$30 \quad r_{17} = 275.832 \quad d_{17} = 6.11$$

$$r_{18} = -1075.96 \quad d_{18} = 10.52 \quad n_{10} = 1.68083 \quad v_{10} = 55.1$$

$$35 \quad r_{19} = -88.713 \quad d_{19} = 0.25$$

$$r_{20} = 128.275 \quad d_{20} = 10.01 \quad n_{11} = 1.7762 \quad v_{11} = 49.4$$

$$40 \quad r_{21} = -276.533 \quad d_{21} = 4.70$$

$$45 \quad r_{22} = 0.000 \quad d_{22} = 41.10 \quad n_{12} = 1.51825 \quad v_{12} = 63.8$$

$$r_{23} = 0.000$$

50 where r_1, r_2, \dots are a radius of curvature of each surface starting from the screen side, d_1, d_2, \dots are a distance between each of said surfaces, n_1, n_2, \dots are a refractive index at an e-line of each lens, and v_1, v_2, \dots are an Abbe's number corresponding to the e-line of each of the above lens.

55 7. A projection lens according to claim 3, wherein at least one surface of the first, second, eighth, ninth, and tenth lenses has an aspheric surface.

8. A projection lens according to claim 7, satisfying substantially the following conditions:

$f = 49.82$

Aperture ratio 1:2.8

EP 0 385 698 A2

Projection magnification 16.94

$\omega = 36.2^\circ$

$f_{1,7} f = 1.05$

$d_{1,5} f = 0.74$

5 $d_{1,7} f = 0.16$

$f_8 f_{9,10} = -1.33$

10 $r_1 = 104.034 \quad d_1 = 11.00 \quad n_1 = 1.49384 \quad v_1 = 57.4 \quad *$

15 $r_2 = 466.780 \quad d_2 = 5.00 \quad *$

20 $r_3 = 73.295 \quad d_3 = 2.00 \quad n_2 = 1.49384 \quad v_2 = 57.4 \quad *$

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$r_4 = 26.295 \quad d_4 = 11.00 \quad *$
 $r_5 = 121.495 \quad d_5 = 2.21 \quad n_5 = 1.52555 \quad v_5 = 50.5$
 $r_6 = 29.715 \quad d_6 = 18.76$
 $r_7 = 74.902 \quad d_7 = 17.33 \quad n_7 = 1.85503 \quad v_7 = 23.7$
 $r_8 = -372.104 \quad d_8 = 6.68$
 $r_9 = 271.686 \quad d_9 = 17.77 \quad n_9 = 1.79013 \quad v_9 = 43.9$
 $r_{10} = -25.786 \quad d_{10} = 2.00 \quad n_{10} = 1.76169 \quad v_{10} = 27.3$
 $r_{11} = 74.081 \quad d_{11} = 4.62$
 $r_{12} = -81.511 \quad d_{12} = 4.50 \quad n_{12} = 1.77622 \quad v_{12} = 49.4$
 $r_{13} = -43.199 \quad d_{13} = 1.49$
 $r_{14} = 204.097 \quad d_{14} = 4.11 \quad n_{14} = 1.79196 \quad v_{14} = 47.1$
 $r_{15} = -122.218 \quad d_{15} = 35.89$
 $r_{16} = -62.109 \quad d_{16} = 2.66 \quad n_{16} = 1.61075 \quad v_{16} = 40.0$
 $r_{17} = 213.114 \quad d_{17} = 7.80$
 $r_{18} = 847.406 \quad d_{18} = 10.30 \quad n_{18} = 1.68083 \quad v_{18} = 55.1$

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$r_{1s} = -95.951 \quad d_{1s} = 0.63$

5 $r_{20} = 121.641 \quad d_{20} = 10.45 \quad n_{11} = 1.77622 \quad v_{11} = 49.4$

$r_{21} = -255.505 \quad d_{21} = 4.50$

10 $r_{22} = 0.000 \quad d_{22} = 41.10 \quad n_{12} = 1.51825 \quad v_{12} = 63.8$

$r_{23} = 0.000$

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Aspheric coefficient

First surface:

$K = 0.655275$

20 $AD = 0.626082 \times 10^{-7}$

$AE = -0.144786 \times 10^{-10}$

$AF = -0.109334 \times 10^{-14}$

Second surface:

$K = 0.367907 \times 10^2$

25 Third surface:

$K = 0.440304$

$AD = 0.126898 \times 10^{-7}$

$AE = 0.634832 \times 10^{-11}$

$AF = 0.928375 \times 10^{-14}$

30 Fourth surface:

$K = -0.241861 \times 10^{-1}$

$AD = 0.166124 \times 10^{-6}$

$AE = 0.434466 \times 10^{-9}$

$AF = 0.561828 \times 10^{-12}$

35 where r_1, r_2, \dots represent a radius of curvature of each surface starting from the screen side, d_1, d_2, \dots represent a distance between each of said surfaces, n_1, n_2, \dots represent a refractive index at an e-line of each lens, v_1, v_2, \dots represent an Abbe's number corresponding to the e-line of each of the above lens, surfaces represented by * ... are the aspheric surfaces, and if Z is supposed a displacement amount from a vertex of a lens at a position away from an optical axis of the lens in a radius distance Y of an opening, it can be expressed as

$$40 Z = \frac{Y^2 / r}{1 + \sqrt{1 - (K+1) \cdot (Y/r)^2}}$$

$$+ AD \cdot Y^4 + AE \cdot Y^6 + AF \cdot Y^8 + AG \cdot Y^{10}$$

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and where AD, AE, AF, and AG are aspherical coefficients, and K is a conical constant.

9. A projection lens according to claim 7, satisfying substantially the following conditions:

$f = 52.47$

Aperture ratio 1:2.8

55 Projection magnification 17.19

$\omega = 33.8^\circ$

$F_{1,7}/f = 1.09$

$d_{15}/f = 0.64$

$d_{17} \cdot f = 0.12$
 $f_8 f_{9,10} = -1.31$

5 $r_1 = 148.519$ $d_1 = 8.40$ $n_1 = 1.51825$ $\nu_1 = 63.8$ *

10 $r_2 = -6939.731$ $d_2 = 5.18$

15 $r_3 = 49.137$ $d_3 = 6.00$ $n_2 = 1.51825$ $\nu_2 = 63.8$

20 $r_4 = 29.177$ $d_4 = 9.37$ *

25 $r_5 = 608.860$ $d_5 = 2.21$ $n_3 = 1.52555$ $\nu_3 = 50.5$

30 $r_6 = 28.525$ $d_6 = 18.76$

35 $r_7 = 74.902$ $d_7 = 17.33$ $n_4 = 1.85503$ $\nu_4 = 23.7$

40 $r_8 = -372.104$ $d_8 = 6.68$

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r₀ = 271.686 d₀ = 17.77 n_s = 1.79013 ν_s = 43.9
 5 r_{1,0} = -25.786 d_{1,0} = 2.00 n_s = 1.76169 ν_s = 27.3
 10 r_{1,1} = 74.081 d_{1,1} = 4.62
 15 r_{1,2} = -81.511 d_{1,2} = 4.50 n_r = 1.77622 ν_r = 49.4
 20 r_{1,3} = -43.199 d_{1,3} = 1.49
 25 r_{1,4} = 204.097 d_{1,4} = 4.11 n_s = 1.79196 ν_s = 47.1
 30 r_{1,5} = -122.218 d_{1,5} = 33.60
 35 r_{1,6} = -49.674 d_{1,6} = 2.66 n_s = 1.62059 ν_s = 36.4
 40 r_{1,7} = 298.959 d_{1,7} = 6.11 *
 45 r_{1,8} = -275.028 d_{1,8} = 10.70 n_{1,0} = 1.68083 ν_{1,0} = 55.1 *
 50 r_{1,9} = -56.037 d_{1,9} = 0.25
 55 r_{2,0} = 341.327 d_{2,0} = 11.05 n_{1,1} = 1.77622 ν_{1,1} = 49.4 *
 60 r_{2,1} = -103.830 d_{2,1} = 6.70
 65 r_{2,2} = 0.000 d_{2,2} = 43.30 n_{1,2} = 1.51825 ν_{1,2} = 63.8
 70 r_{2,3} = 0.000

Aspheric coefficient

First surface:

$$K = -0.2749912 \times 10^{-1}$$

$$AD = 0.2548179 \times 10^{-7}$$

$$\Delta E = -0.2056712 \times 10^{-10}$$

$$AF = -0.4319405 \times 10^{-14}$$

AG = 0.8811238

Fourth surface:

$$K = 0.3668809 \times 10^{-1}$$

$$AD = 0.1536691 \times 10^{-6}$$

$$AE = -0.1142634 \times 10^{-10}$$

$$AF = 0.8573753 \times 10^{-12}$$

Seventeenth surface:

$$K = 0.2637872 \times 10^2$$

$$AD = 0.1858271 \times 10^{-6}$$

$$AE = 0.1334531 \times 10^{-10}$$

$$5 AF = 0.2612238 \times 10^{-13}$$

$$AG = 0.9178511 \times 10^{-17}$$

Eighteenth surface

$$K = 0.5903051 \times 10^1$$

$$AD = -0.2472130 \times 10^{-6}$$

$$10 AE = 0.1460313 \times 10^{-9}$$

$$AF = 0.3400976 \times 10^{-13}$$

$$AG = 0.3706282 \times 10^{-17}$$

Twentieth surface:

$$K = -0.9201606$$

$$15 AD = -0.1022347 \times 10^{-6}$$

$$AE = 0.7465995 \times 10^{-10}$$

$$AF = 0.1567219 \times 10^{-13}$$

$$AG = 0.1032802 \times 10^{-17}$$

where r_1, r_2, \dots represent a radius of curvature of each surface starting from the screen side, d_1, d_2, \dots represents a distance between each of said surfaces, n_1, n_2, \dots represents a refractive index at an e-line of each lens, v_1, v_2, \dots represents an Abbe's number corresponding to the e-line of each of the above lens, surfaces represented by \dots are the aspheric surfaces, and if Z is supposed a displacement amount from a vertex of a lens at a position away from an optical axis of the lens in a radius distance Y of an opening, it can be expressed as

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$$Z = \frac{Y^2 / r}{1 + \sqrt{1 - (K+1) \cdot (Y/r)^2}} + AD \cdot Y^4 + AE \cdot Y^6 + AF \cdot Y^8 + AG \cdot Y^{10}$$

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35 and where AD, AE, AF, and AG are aspherical coefficients, and K is a conical constant.
10. A projection lens according to claim 7, satisfying substantially the following conditions:

$$F = 49.94$$

Aperture ratio 1:2.8

Projection magnification 18.09

$$40 \omega = 34.1^\circ$$

$$f_{1,7}/f = 1.14$$

$$d_{1,5}/f = 0.67$$

$$d_{1,7}/f = 0.12$$

$$f_8/f_{9,10} = -1.37$$

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1 $r_1 = 146.163$ $d_1 = 8.40$ $n_1 = 1.51825$ $\nu_1 = 63.8$ *

5 $r_2 = 0.000$ $d_2 = 5.18$

10 $r_3 = 49.670$ $d_3 = 6.00$ $n_3 = 1.51825$ $\nu_3 = 63.8$

15 $r_4 = 29.101$ $d_4 = 9.39$ *

20 $r_5 = 937.536$ $d_5 = 2.21$ $n_5 = 1.52555$ $\nu_5 = 50.5$

25 $r_6 = 28.141$ $d_6 = 18.76$

30 $r_7 = 74.902$ $d_7 = 17.33$ $n_7 = 1.85503$ $\nu_7 = 23.7$

35 $r_8 = -372.104$ $d_8 = 6.68$

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$r_0 = 271.686 \quad d_0 = 17.77 \quad n_s = 1.79013 \quad \nu_s = 43.9$

5 $r_{1,0} = -25.786 \quad d_{1,0} = 2.00 \quad n_s = 1.76169 \quad \nu_s = 27.3$

10 $r_{1,1} = 74.081 \quad d_{1,1} = 4.62$

15 $r_{1,2} = -81.511 \quad d_{1,2} = 4.50 \quad n_s = 1.77622 \quad \nu_s = 49.4$

20 $r_{1,3} = -43.199 \quad d_{1,3} = 1.49$

25 $r_{1,4} = 204.097 \quad d_{1,4} = 4.11 \quad n_s = 1.79196 \quad \nu_s = 47.1$

30 $r_{1,5} = -122.218 \quad d_{1,5} = 33.60$

35 $r_{1,6} = -49.674 \quad d_{1,6} = 2.66 \quad n_s = 1.62059 \quad \nu_s = 36.4$

40 $r_{1,7} = 303.305 \quad d_{1,7} = 6.11 \quad *$

45 $r_{1,8} = -310.381 \quad d_{1,8} = 10.70 \quad n_s = 1.68083 \quad \nu_s = 55.1 \quad *$

50 $r_{1,9} = -54.486 \quad d_{1,9} = 0.25$

55 $r_{2,0} = 275.356 \quad d_{2,0} = 11.05 \quad n_{1,1} = 1.77622 \quad \nu_{1,1} = 49.4 \quad *$

60 $r_{2,1} = -108.456 \quad d_{2,1} = 6.70$

65 $r_{2,2} = 0.000 \quad d_{2,2} = 43.30 \quad n_{1,2} = 1.51825 \quad \nu_{1,2} = 63.8$

70 $r_{2,3} = 0.000$

75 Aspheric coefficient
First surface:

K = $-0.2301050 \times 10^{-1}$

AD = 0.2511178×10^{-7}

80 AE = $-0.1943356 \times 10^{-10}$

AF = $-0.3619595 \times 10^{-14}$

AG = $0.8095271 \times 10^{-18}$

Fourth surface:

K = 0.3295092×10^{-1}

85 AD = $-0.4594244 \times 10^{-7}$

AE = $0.7461787 \times 10^{-10}$

AF = $0.4135199 \times 10^{-12}$

AG = $-0.3071122 \times 10^{-15}$

Seventeenth surface:

$$K = 0.2504243 \times 10^2$$

$$AD = 0.1782731 \times 10^{-6}$$

$$AE = -0.1529465 \times 10^{-11}$$

5 AF = $0.2164382 \times 10^{-13}$

$$AG = -0.7725707 \times 10^{-17}$$

Eighteenth surface:

$$K = 0.1032711 \times 10^2$$

$$AD = -0.2772488 \times 10^{-6}$$

10 AE = 0.1544648×10^{-9}

$$AF = 0.2193979 \times 10^{-13}$$

$$AG = -0.1042978 \times 10^{-16}$$

Twentieth surface:

$$K = -0.5525461 \times 10^1$$

15 AD = $-0.1231838 \times 10^{-6}$

$$AE = 0.8516421 \times 10^{-10}$$

$$AF = 0.1510178 \times 10^{-13}$$

$$AG = 0.1229936 \times 10^{-18}$$

where r_1, r_2, \dots represent a radius of curvature of each surface starting from the screen side, d_1, d_2, \dots
 20 represent a distance between each of said surfaces, n_1, n_2, \dots represent a refractive index at an e-line of each lens, v_1, v_2, \dots represent an Abbe's number corresponding to the e-line of each of the above lens, surfaces represented by * ... are the aspheric surfaces, and if Z is supposed a displacement amount from a vertex of a lens at a position away from an optical axis of the lens in a radius distance Y of an opening, it can be expressed as

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$$Y^2 / r$$

$$Z = \frac{Y^2 / r}{1 + \sqrt{1 - (K+1) \cdot (Y/r)^2}}$$

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$$+ AD \cdot Y^4 + AE \cdot Y^6 + AF \cdot Y^8 + AG \cdot Y^{10}$$

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and where AD, AE, AF, and AG are aspherical coefficients, and K is a conical constant.

11. A projection lens according to claim 7, satisfying substantially the following conditions:

$$f = 50.00$$

Aperture ratio 1:2.8

40 Projection magnification 18.10

$$\omega = 34.0^\circ$$

$$f_{17}/f = 1.14$$

$$d_{15}/f = 0.67$$

$$d_{17}/f = 0.12$$

45 $f_8/f_{9,10} = -1.35$

1 r₁ = 139.093 d₁ = 8.40 n₁ = 1.51825 v₁ = 63.8 *

5 r₂ = 1883.809 d₂ = 5.18

r₃ = 44.322 d₃ = 6.00 n₂ = 1.51825 v₂ = 63.8

10 r₄ = 26.610 d₄ = 11.06

r₅ = 1031.968 d₅ = 2.21 n₃ = 1.52555 v₃ = 50.5

15 r₆ = 28.804 d₆ = 18.76

20 r₇ = 74.902 d₇ = 17.33 n₄ = 1.85503 v₄ = 23.7

r₈ = -372.104 d₈ = 6.68

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$r_9 = 271.686$ $d_9 = 17.77$ $n_s = 1.79013$ $\nu_s = 43.9$

5 $r_{10} = -25.786$ $d_{10} = 2.00$ $n_s = 1.76169$ $\nu_s = 27.3$

$r_{11} = 74.081$ $d_{11} = 4.62$

10 $r_{12} = -81.511$ $d_{12} = 4.50$ $n_s = 1.77622$ $\nu_s = 49.4$

$r_{13} = -43.199$ $d_{13} = 1.49$

15 $r_{14} = 204.097$ $d_{14} = 4.11$ $n_s = 1.79196$ $\nu_s = 47.1$

20 $r_{15} = -122.218$ $d_{15} = 33.60$

$r_{16} = -48.652$ $d_{16} = 2.66$ $n_s = 1.62059$ $\nu_s = 36.4$

25 $r_{17} = 293.965$ $d_{17} = 6.11$ *

$r_{18} = -406.452$ $d_{18} = 10.70$ $n_s = 1.68083$ $\nu_s = 55.1$ *

30 $r_{19} = -56.325$ $d_{19} = 0.25$

$r_{20} = 243.391$ $d_{20} = 11.05$ $n_s = 1.77622$ $\nu_s = 49.4$

35 $r_{21} = -112.964$ $d_{21} = 6.70$

40 $r_{22} = 0.000$ $d_{22} = 43.30$ $n_s = 1.51825$ $\nu_s = 63.8$

$r_{23} = 0.000$

45 Aspheric coefficient

First surface:

$K = 0.3664325$

$AD = 0.4574458 \times 10^{-7}$

50 $AE = -0.3507965 \times 10^{-10}$

$AF = 0.2388062 \times 10^{-14}$

$AG = 0.2247566 \times 10^{-19}$

Seventeenth surface:

$K = 0.1229070 \times 10^2$

55 $AD = 0.9272514 \times 10^{-7}$

$AE = -0.3770400 \times 10^{-10}$

$AF = 0.1428259 \times 10^{-12}$

$AG = 0.5601794 \times 10^{-16}$

Eighteenth surface:

$$K = 0.2118076 \times 10^2$$

$$AD = -0.4127061 \times 10^{-6}$$

$$AE = 0.2205876 \times 10^{-9}$$

$$5 AF = 0.6059036 \times 10^{-13}$$

$$AG = 0.6235547 \times 10^{-16}$$

where r_1, r_2, \dots represent a radius of curvature of each surface starting from the screen side, d_1, d_2, \dots represent a distance between each of said surfaces, n_1, n_2, \dots represent a refractive index at an e-line of each lens, ν_1, ν_2, \dots represent an Abbe's number corresponding to the e-line of each of the above lens.
 10 surfaces represented by $\cdot \dots$ are the aspheric surfaces, and if Z is supposed a displacement amount from a vertex of a lens at a position away from an optical axis of the lens in a radius distance Y of an opening, it can be expressed as

$$15 Z = \frac{Y^2 / r}{1 + \sqrt{1 - (K+1) \cdot (Y/r)^2}}$$

$$20 + AD \cdot Y^4 + AE \cdot Y^6 + AF \cdot Y^8 + AG \cdot Y^{10}$$

and where AD, AE, AF, and AG are aspherical coefficients, and K is a conical constant.

25 12. A projection lens according to claim 7, satisfying substantially the following conditions:

$$F = 50.15$$

Aperture ratio 1:2.8

Projection magnification 18.09

$$\omega = 34.1$$

$$30 f_{17}/f = 1.15$$

$$d_{15}/f = 0.67$$

$$d_{17}/f = 0.12$$

$$f_8/f_{9,10} = -1.33$$

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EP 0 385 698 A2

1 $r_1 = 138.102$ $d_1 = 8.40$ $n_1 = 1.51825$ $\nu_1 = 63.8$ *

5 $r_2 = 3278.162$ $d_2 = 5.18$

10 $r_3 = 48.685$ $d_3 = 6.00$ $n_3 = 1.51825$ $\nu_3 = 63.8$

15 $r_4 = 29.654$ $d_4 = 11.06$

20 $r_5 = 1869.065$ $d_5 = 2.21$ $n_5 = 1.52555$ $\nu_5 = 50.5$

25 $r_6 = 27.929$ $d_6 = 18.76$

30 $r_7 = 74.902$ $d_7 = 17.33$ $n_7 = 1.85503$ $\nu_7 = 23.7$

35 $r_8 = -372.104$ $d_8 = 6.68$

40 $r_9 = 271.686$ $d_9 = 17.77$ $n_9 = 1.79013$ $\nu_9 = 43.9$

45 $r_{10} = -25.786$ $d_{10} = 2.00$ $n_{10} = 1.76169$ $\nu_{10} = 27.3$

50 $r_{11} = 74.081$ $d_{11} = 4.62$

55 $r_{12} = -81.511$ $d_{12} = 4.50$ $n_{12} = 1.77622$ $\nu_{12} = 49.4$

60 $r_{13} = -43.199$ $d_{13} = 1.49$

65 $r_{14} = 204.097$ $d_{14} = 4.11$ $n_{14} = 1.79196$ $\nu_{14} = 47.1$

70 $r_{15} = -122.218$ $d_{15} = 33.60$

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$r_{1,6} = -45.791$ $d_{1,6} = 2.66$ $n_6 = 1.62059$ $\nu_6 = 36.4$

5 $r_{1,7} = 288.771$ $d_{1,7} = 6.11$ *

$r_{1,8} = -339.448$ $d_{1,8} = 11.20$ $n_{1,8} = 1.68083$ $\nu_{1,8} = 55.1$

10 $r_{1,9} = -52.879$ $d_{1,9} = 0.25$

$r_{2,0} = 237.092$ $d_{2,0} = 11.05$ $n_{1,1} = 1.77622$ $\nu_{1,1} = 49.4$ *

15 $r_{2,1} = -107.581$ $d_{2,1} = 6.70$

20 $r_{2,2} = 0.000$ $d_{2,2} = 43.30$ $n_{1,2} = 1.51825$ $\nu_{1,2} = 63.8$

$r_{2,3} = 0.000$

25 Aspheric coefficient
First surface:

K = -0.8676696
 $AD = 0.4922937 \times 10^{-7}$

30 AE = $-0.2681624 \times 10^{-10}$
 $AF = 0.4039305 \times 10^{-14}$

AG = $-0.6315714 \times 10^{-18}$
Seventeenth surface:

K = 0.1204351×10^2
 $AD = 0.8134826 \times 10^{-7}$

AE = $0.3285905 \times 10^{-11}$
 $AF = -0.3382158 \times 10^{-13}$

AG = $0.1685514 \times 10^{-16}$
Twentieth surface:

40 K = -0.1760054×10^2
 $AD = -0.2229407 \times 10^{-6}$

AE = $0.8474120 \times 10^{-10}$
 $AF = 0.3501296 \times 10^{-13}$

AG = $-0.6162020 \times 10^{-17}$

45 where r_1, r_2, \dots represent a radius of curvature of each surface starting from the screen side, d_1, d_2, \dots represent a distance between each of said surfaces, n_1, n_2, \dots represent a refractive index at an e-line of each lens, ν_1, ν_2, \dots represent an Abbe's number corresponding to the e-line of each of the above lens, surfaces represented by * ... are the aspheric surfaces, and if Z is supposed a displacement amount from a vertex of a lens at a position away from an optical axis of the lens in a radius distance Y of an opening, it

50 can be expressed as

$$Z = \frac{Y^2 / r}{1 + \sqrt{1 - (K+1) \cdot (Y/r)^2}}$$

5

$$+ AD \cdot Y^4 + AE \cdot Y^6 + AF \cdot Y^8 + AG \cdot Y^{10}$$

10 and where AD, AE, AF, and AG are aspherical coefficients, and K is a conical constant.

13. A projection lens according to claim 7, satisfying substantially the following conditions:

$$f = 49.98$$

$$\text{Aperture ratio } 1:2.8$$

$$\text{Projection magnification } 18.09$$

$$15 \omega = 34.2^\circ$$

$$f_1, f = 1.16$$

$$d_{1,5}, f = 0.67$$

$$d_{1,7}, f = 0.12$$

$$f_8, f_{9,10} = -1.35$$

20

$$r_1 = 97.304 \quad d_1 = 8.40 \quad n_1 = 1.51825 \quad \nu_1 = 63.8$$

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$$r_2 = 419.135 \quad d_2 = 5.18$$

$$r_3 = 71.654 \quad d_3 = 6.00 \quad n_2 = 1.51825 \quad \nu_2 = 63.8$$

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$$r_4 = 34.797 \quad d_4 = 7.04$$

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$r_5 = 373.100 \quad d_5 = 2.21 \quad n_5 = 1.52555 \quad v_5 = 50.5$
 $r_6 = 27.138 \quad d_6 = 18.76$
 $r_7 = 74.902 \quad d_7 = 17.33 \quad n_7 = 1.85503 \quad v_7 = 23.7$
 $r_8 = -372.104 \quad d_8 = 6.68$
 $r_9 = 271.686 \quad d_9 = 17.77 \quad n_9 = 1.79013 \quad v_9 = 43.9$
 $r_{10} = -25.786 \quad d_{10} = 2.00 \quad n_{10} = 1.76169 \quad v_{10} = 27.3$
 $r_{11} = 74.081 \quad d_{11} = 4.62$
 $r_{12} = -81.511 \quad d_{12} = 4.50 \quad n_{12} = 1.77622 \quad v_{12} = 49.4$
 $r_{13} = -43.199 \quad d_{13} = 1.49$
 $r_{14} = 204.097 \quad d_{14} = 4.11 \quad n_{14} = 1.79196 \quad v_{14} = 47.1$
 $r_{15} = -122.218 \quad d_{15} = 33.60$
 $r_{16} = -47.158 \quad d_{16} = 2.66 \quad n_{16} = 1.62059 \quad v_{16} = 36.4$
 $r_{17} = 234.453 \quad d_{17} = 6.11 \quad *$
 $r_{18} = -282.754 \quad d_{18} = 10.70 \quad n_{18} = 1.68083 \quad v_{18} = 55.1 \quad *$
 $r_{19} = -50.375 \quad d_{19} = 0.25$
 $r_{20} = 387.424 \quad d_{20} = 11.05 \quad n_{20} = 1.77622 \quad v_{20} = 49.4 \quad *$
 $r_{21} = -89.653 \quad d_{21} = 6.70$
 $r_{22} = 0.000 \quad d_{22} = 43.30 \quad n_{22} = 1.51825 \quad v_{22} = 63.8$
 $r_{23} = 0.000$

Aspheric coefficient

Seventeenth surface:

$$K = 0.3064228 \times 10^2$$

$$AD = 0.3424168 \times 10^{-6}$$

5 AE = 0.1524318 $\times 10^{-11}$

$$AF = 0.2578158 \times 10^{-14}$$

$$AG = -0.1657459 \times 10^{-16}$$

Eighteenth surface:

$$K = -0.1540423 \times 10^2$$

10 AD = -0.1423166 $\times 10^{-6}$

$$AE = 0.2421751 \times 10^{-9}$$

$$AF = 0.9010286 \times 10^{-13}$$

$$AG = 0.6174771 \times 10^{-16}$$

Twentieth surface:

15 K = -0.1023903 $\times 10^3$

$$AD = -0.2301108 \times 10^{-6}$$

$$AE = 0.1076672 \times 10^{-9}$$

$$AF = -0.1514403 \times 10^{-14}$$

$$AG = -0.3385086 \times 10^{-17}$$

20 where r_1, r_2, \dots represent a radius of curvature of each surface starting from the screen side, d_1, d_2, \dots represent a distance between each of said surfaces, n_1, n_2, \dots represent a refractive index at an e-line of each lens, v_1, v_2, \dots represent an Abbe's number corresponding to the e-line of each of the above lens, surfaces represented by * ... are the aspheric surfaces, and if Z is supposed a displacement amount from a vertex of a lens at a position away from an optical axis of the lens in a radius distance Y of an opening, it
25 can be expressed as

$$Y^2 / r$$

30 $Z = \frac{Y^2 / r}{1 + \sqrt{1 - (K+1) \cdot (Y/r)^2}}$

$$+ AD \cdot Y^4 + AE \cdot Y^6 + AF \cdot Y^8 + AG \cdot Y^{10}$$

35

and where AD, AE, AF, and AG are aspherical coefficients, and K is a conical constant.

14. A projection lens according to claim 7, satisfying substantially the following conditions:

$$f = 50.09$$

40 Aperture ratio 1:2.8

Projection magnification 18.09

$$\omega = 34.1^\circ$$

$$f_{1.7}/f = 1.13$$

$$d_{15}/f = 0.67$$

45 $d_{17}/f = 0.12$

$$f_8/f_{9.10} = -1.34$$

50

EP 0 385 698 A2

55 $r_1 = 100.392$ $d_1 = 8.40$ $n_1 = 1.51825$ $\nu_1 = 63.8$ *

5 $r_2 = 203.275$ $d_2 = 5.18$

10 $r_3 = 39.627$ $d_3 = 6.00$ $n_2 = 1.51825$ $\nu_2 = 63.8$

15 $r_4 = 24.889$ $d_4 = 12.47$

20 $r_5 = 566.809$ $d_5 = 2.21$ $n_3 = 1.52555$ $\nu_3 = 50.5$

25 $r_6 = 29.209$ $d_6 = 18.76$

30 $r_7 = 74.902$ $d_7 = 17.33$ $n_4 = 1.85503$ $\nu_4 = 23.7$

35 $r_8 = -372.104$ $d_8 = 6.68$

40 $r_9 = 271.686$ $d_9 = 17.77$ $n_5 = 1.79013$ $\nu_5 = 43.9$

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EP 0 385 698 A2

$r_{1,0} = -25.786$ $d_{1,0} = 2.00$ $n_1 = 1.76169$ $\nu_1 = 27.3$

5 $r_{1,1} = 74.081$ $d_{1,1} = 4.62$

$r_{1,2} = -81.511$ $d_{1,2} = 4.50$ $n_2 = 1.77622$ $\nu_2 = 49.4$

10 $r_{1,3} = -43.199$ $d_{1,3} = 1.49$

15 $r_{1,4} = 204.097$ $d_{1,4} = 4.11$ $n_3 = 1.79196$ $\nu_3 = 47.1$

20 $r_{1,5} = -122.218$ $d_{1,5} = 35.89$

25 $r_{1,6} = -49.808$ $d_{1,6} = 2.66$ $n_4 = 1.62059$ $\nu_4 = 36.4$

$r_{1,7} = 275.553$ $d_{1,7} = 6.11$ *

30 $r_{1,8} = -519.026$ $d_{1,8} = 10.70$ $n_{1,0} = 1.68083$ $\nu_{1,0} = 55.1$

$r_{1,9} = -60.159$ $d_{1,9} = 0.25$

35 $r_{2,0} = 250.814$ $d_{2,0} = 11.05$ $n_{1,1} = 1.77622$ $\nu_{1,1} = 49.4$

$r_{2,1} = -108.683$ $d_{2,1} = 6.70$

40 $r_{2,2} = 0.000$ $d_{2,2} = 43.30$ $n_{1,2} = 1.51825$ $\nu_{1,2} = 63.8$

$r_{2,3} = 0.000$

45

Aspheric coefficient

First surface:

$K = 0.9525501$

$AD = 0.2216984 \times 10^{-6}$

$AE = -0.4500812 \times 10^{-10}$

$AF = 0.1270679 \times 10^{-13}$

$AG = -0.2481052 \times 10^{-17}$

50 Seventeenth surface:

$K = 0.3154613 \times 10^2$

$AD = 0.5889586 \times 10^{-6}$

$AE = -0.5654111 \times 10^{-9}$

$AF = 0.5498361 \times 10^{-13}$

55 $AG = 0.2775640 \times 10^{-16}$

where r_1, r_2, \dots represent a radius of curvature of each surface starting from the screen side, d_1, d_2, \dots represent a distance between each of said surfaces, n_1, n_2, \dots represent a refractive index at an e-line of each lens, ν_1, ν_2, \dots represent an Abbe's number corresponding to the e-line of each of the above lens,

surfaces represented by * ... are the aspheric surfaces, and if Z is supposed a displacement amount from a vertex of a lens at a position away from an optical axis of the lens in a radius distance Y of an opening, it can be expressed as

5

$$Z = \frac{Y^2 / r}{1 + \sqrt{1 - (K+1) \cdot (Y/r)^2}} + AD \cdot Y^4 + AE \cdot Y^6 + AF \cdot Y^8 + AG \cdot Y^{10}$$

10

and where AD, AE, AF, and AG are aspherical coefficients, and K is a conical constant.

15 15. A projection lens according to claim 7, satisfying substantially the following conditions:

$$f = 49.91$$

Aperture ratio 1:2.8

Projection magnification 18.07

$$\omega = 34.2$$

$$f_{1,7}f = 1.13$$

$$d_{15}/f = 0.67$$

$$d_{17}/f = 0.12$$

$$f_8/f_{9,10} = -1.39$$

25

$$r_1 = 92.116 \quad d_1 = 8.40 \quad n_1 = 1.51825 \quad \nu_1 = 63.8 \quad *$$

30

$$r_2 = 256.167 \quad d_2 = 5.18$$

$$r_3 = 60.670 \quad d_3 = 6.00 \quad n_2 = 1.51825 \quad \nu_2 = 63.8$$

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$$r_4 = 29.056 \quad d_4 = 8.80$$

$$5 \quad r_5 = 222.628 \quad d_5 = 2.21 \quad n_5 = 1.52555 \quad \nu_5 = 50.5$$

$$r_6 = 28.187 \quad d_6 = 18.76$$

$$10 \quad r_7 = 74.902 \quad d_7 = 17.33 \quad n_7 = 1.85503 \quad \nu_7 = 23.7$$

$$r_8 = -372.104 \quad d_8 = 6.68$$

$$15 \quad r_9 = 271.686 \quad d_9 = 17.77 \quad n_9 = 1.79013 \quad \nu_9 = 43.9$$

$$20 \quad r_{10} = -25.786 \quad d_{10} = 2.00 \quad n_{10} = 1.76169 \quad \nu_{10} = 27.3$$

$$r_{11} = 74.081 \quad d_{11} = 4.62$$

$$25 \quad r_{12} = -81.511 \quad d_{12} = 4.50 \quad n_{12} = 1.77622 \quad \nu_{12} = 49.4$$

$$r_{13} = -43.199 \quad d_{13} = 1.49$$

$$30 \quad r_{14} = 204.097 \quad d_{14} = 4.11 \quad n_{14} = 1.79196 \quad \nu_{14} = 47.1$$

$$r_{15} = -122.218 \quad d_{15} = 35.89$$

$$35 \quad r_{16} = -55.629 \quad d_{16} = 2.66 \quad n_{16} = 1.62059 \quad \nu_{16} = 36.4$$

$$r_{17} = 243.662 \quad d_{17} = 6.11$$

$$40 \quad r_{18} = -319.338 \quad d_{18} = 10.70 \quad n_{18} = 1.68083 \quad \nu_{18} = 55.1 \quad *$$

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$$r_{1,9} = -61.756 \quad d_{1,9} = 0.25$$

$$r_{2,0} = 302.607 \quad d_{2,0} = 11.05 \quad n_{1,1} = 1.77622 \quad \nu_{1,1} = 49.4$$

$$r_{2,1} = -96.776 \quad d_{2,1} = 6.70$$

$$r_{2,2} = 0.000 \quad d_{2,2} = 43.30 \quad n_{1,2} = 1.51825 \quad \nu_{1,2} = 63.8$$

$$r_{2,3} = 0.000$$

15

Aspheric coefficient

First surface:

$$K = 0.3399632$$

$$AD = 0.7523389 \times 10^{-7}$$

$$AE = -0.6005325 \times 10^{-10}$$

$$AF = 0.2647887 \times 10^{-13}$$

$$AG = -0.5935675 \times 10^{-17}$$

Eighteenth surface:

$$K = 0.2756654 \times 10^2$$

$$AD = -0.7554289 \times 10^{-6}$$

$$AE = 0.3478933 \times 10^{-9}$$

$$AF = -0.7082334 \times 10^{-13}$$

$$AG = 0.2544740 \times 10^{-16}$$

where r_1, r_2, \dots represent a radius of curvature of each surface starting from the screen side, d_1, d_2, \dots represent a distance between each of said surfaces, n_1, n_2, \dots represent a refractive index at an e-line of each lens, ν_1, ν_2, \dots represent an Abbe's number corresponding to the e-line of each of the above lens, surfaces represented by \dots are the aspheric surfaces, and if Z is supposed a displacement amount from a vertex of a lens at a position away from an optical axis of the lens in a radius distance Y of an opening, it can be expressed as

35

$$Y^2 / r$$

40

$$Z = \frac{Y^2 / r}{1 + \sqrt{1 - (K + 1) \cdot (Y / r)^2}}$$

$$+ AD \cdot Y^4 + AE \cdot Y^6 + AF \cdot Y^8 + AG \cdot Y^{10}$$

45

and where AD, AE, AF, and AG are aspherical coefficients, and K is a conical constant.

16. A projection lens according to claim 7, satisfying substantially the following conditions:

$$f = 50.04$$

Aperture ratio 1:2.8

50 Projection magnification 18.10

$$\omega = 34.2^\circ$$

$$f_{1,7}/f = 1.14$$

$$d_{15}/f = 0.67$$

$$d_{17}/f = 0.12$$

$$55 f_8/f_{9,10} = -1.31$$

1 r₁ = 114.457 d₁ = 8.40 n₁ = 1.51825 v₁ = 63.8 *

5 r₂ = 483.920 d₂ = 5.18

r₃ = 48.101 d₃ = 6.00 n₂ = 1.51825 v₂ = 63.8

10 r₄ = 28.146 d₄ = 9.91

r₅ = 575.308 d₅ = 2.21 n₃ = 1.52555 v₃ = 50.5

15 r₆ = 28.386 d₆ = 18.76

20 r₇ = 74.902 d₇ = 17.33 n₄ = 1.85503 v₄ = 23.7

r₈ = -372.104 d₈ = 6.68

25 r₉ = 271.686 d₉ = 17.77 n₅ = 1.79013 v₅ = 43.9

r₁₀ = -25.786 d₁₀ = 2.00 n₆ = 1.76169 v₆ = 27.3

30 r₁₁ = 74.081 d₁₁ = 4.62

r₁₂ = -81.511 d₁₂ = 4.50 n₇ = 1.77622 v₇ = 49.4

35 r₁₃ = -43.199 d₁₃ = 1.49

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55

$r_{14} = 204.097 \quad d_{14} = 4.11 \quad n_8 = 1.79196 \quad \nu_8 = 47.1$

5 $r_{15} = -122.218 \quad d_{15} = 33.60$

$r_{16} = -46.081 \quad d_{16} = 2.66 \quad n_9 = 1.62059 \quad \nu_9 = 36.4$

10 $r_{17} = 228.576 \quad d_{17} = 6.11$

$r_{18} = -509.475 \quad d_{18} = 10.70 \quad n_{10} = 1.68083 \quad \nu_{10} = 55.1$

15 $r_{19} = -54.905 \quad d_{19} = 0.25$

20 $r_{20} = 238.750 \quad d_{20} = 11.05 \quad n_{11} = 1.77622 \quad \nu_{11} = 49.4 *$

25 $r_{21} = -103.160 \quad d_{21} = 6.70$

30 $r_{22} = 0.000 \quad d_{22} = 43.30 \quad n_{12} = 1.51825 \quad \nu_{12} = 63.8$

$r_{23} = 0.000$

35 Aspheric coefficient

First surface:

$K = 0.7070278$

$AD = 0.1345127 \times 10^{-7}$

35 $AE = -0.3754727 \times 10^{-10}$

$AF = 0.6046046 \times 10^{-14}$

$AG = -0.1657469 \times 10^{-17}$

Twentieth surface:

$K = -0.1850460 \times 10^2$

40 $AD = -0.2560358 \times 10^{-6}$

$AE = 0.6946116 \times 10^{-10}$

$AF = 0.3196880 \times 10^{-13}$

$AG = -0.5231959 \times 10^{-17}$

where r_1, r_2, \dots represent a radius of curvature of each surface starting from the screen side, d_1, d_2, \dots represent a distance between each of said surfaces, n_1, n_2, \dots represent a refractive index at an e-line of each lens, ν_1, ν_2, \dots represent an Abbe's number corresponding to the e-line of each of the above lens, surfaces represented by * ... are the aspheric surfaces, and if Z is supposed a displacement amount from a vertex of a lens at a position away from an optical axis of the lens in a radius distance Y of an opening, it can be expressed as

$$Z = \frac{Y^2 / r}{1 + \sqrt{1 - (K+1) \cdot (Y/r)^2}}$$

$$+ AD \cdot Y^4 + AE \cdot Y^6 + AF \cdot Y^8 + AG \cdot Y^{10}$$

10 and where AD, AE, AF, and AG are aspherical coefficients, and K is a conical constant.

17. A projection television system comprising; a light source; an image display device having angle-of-view dependency forming images as changes of transmittance or reflectivity by means of electric signals; a projection lens, which has telecentric characteristics, magnifyingly projecting transmission or reflection light
15 from said image display device by having light coming into said image display device having the angle-of-view dependency.

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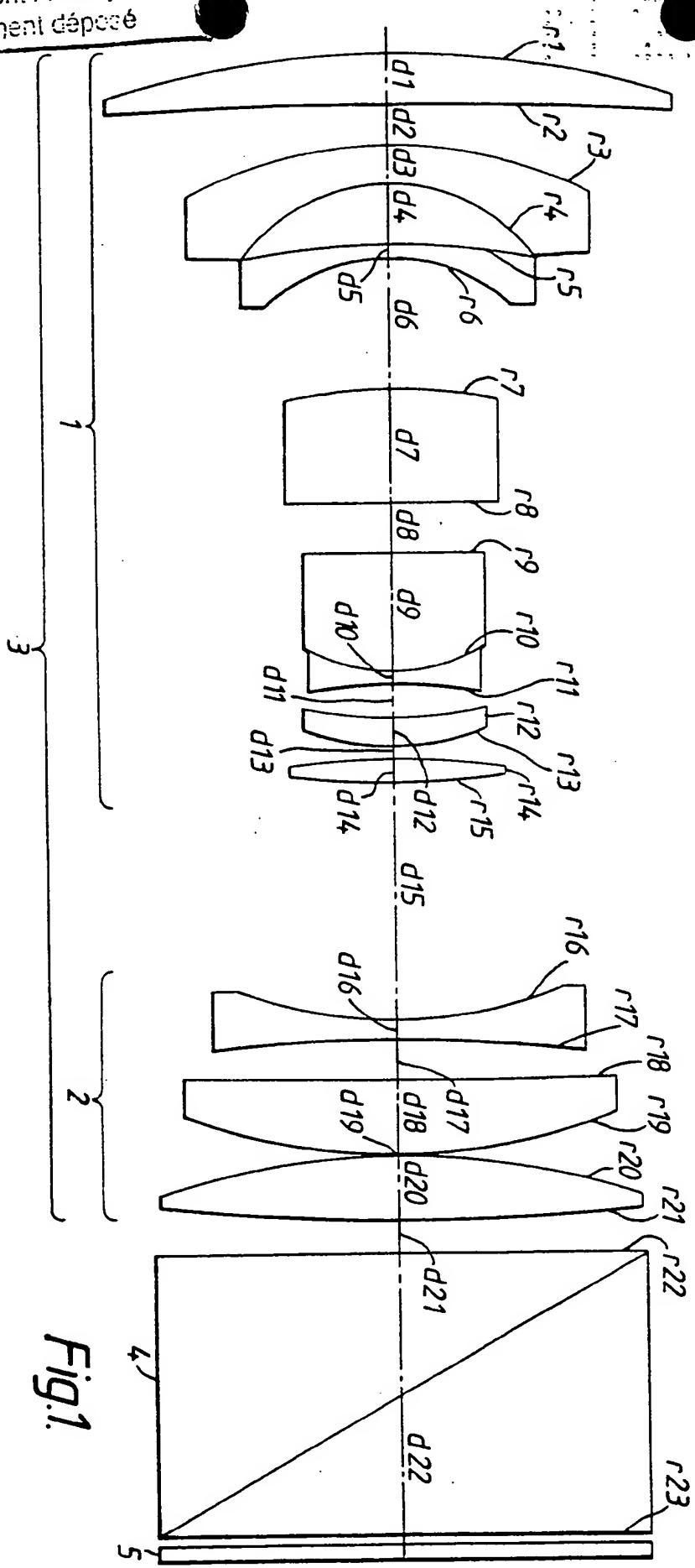
40

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Fig. 1



6-9

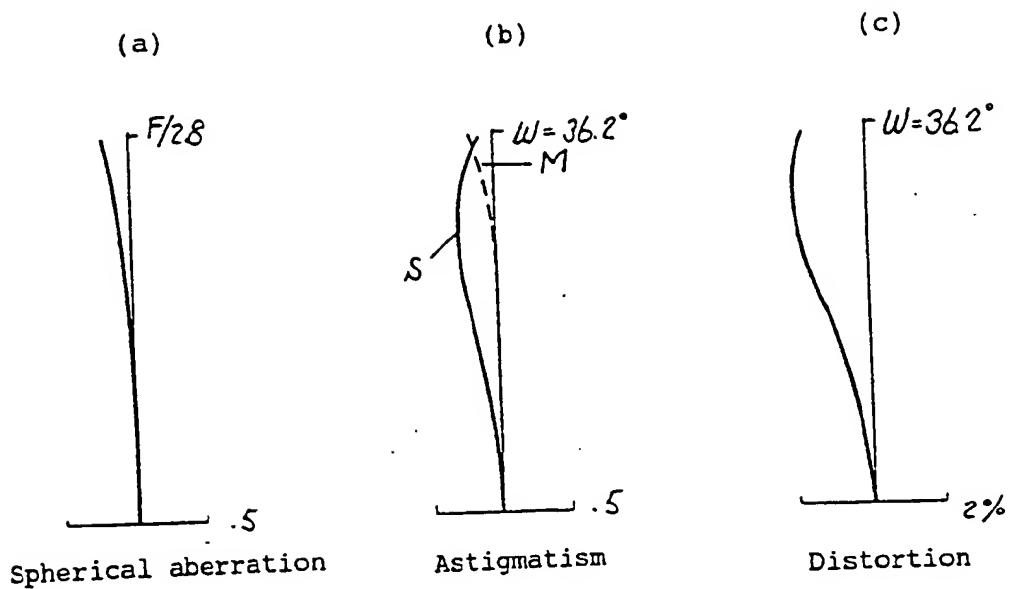


Fig. 2

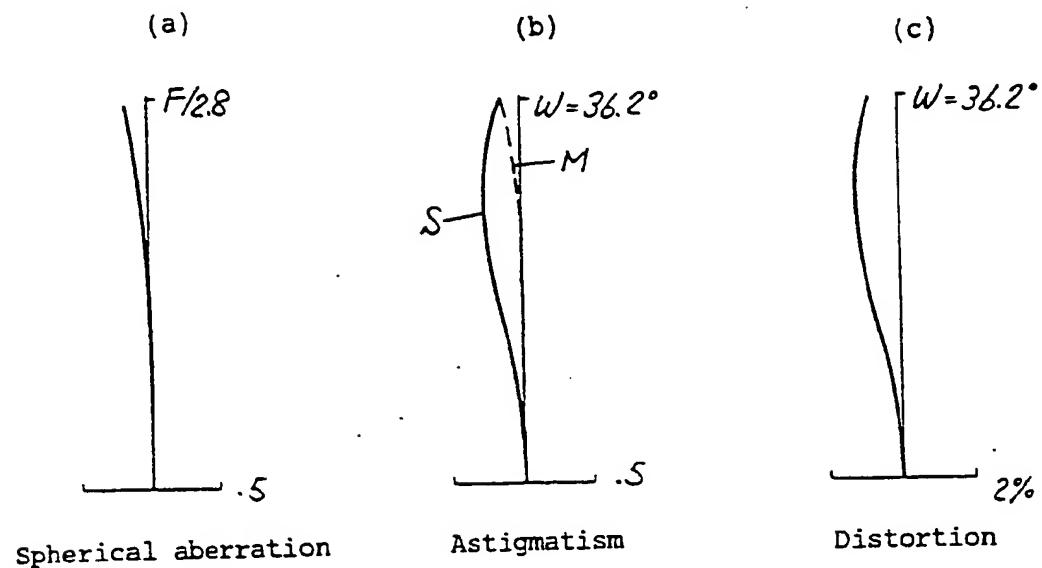


Fig. 3

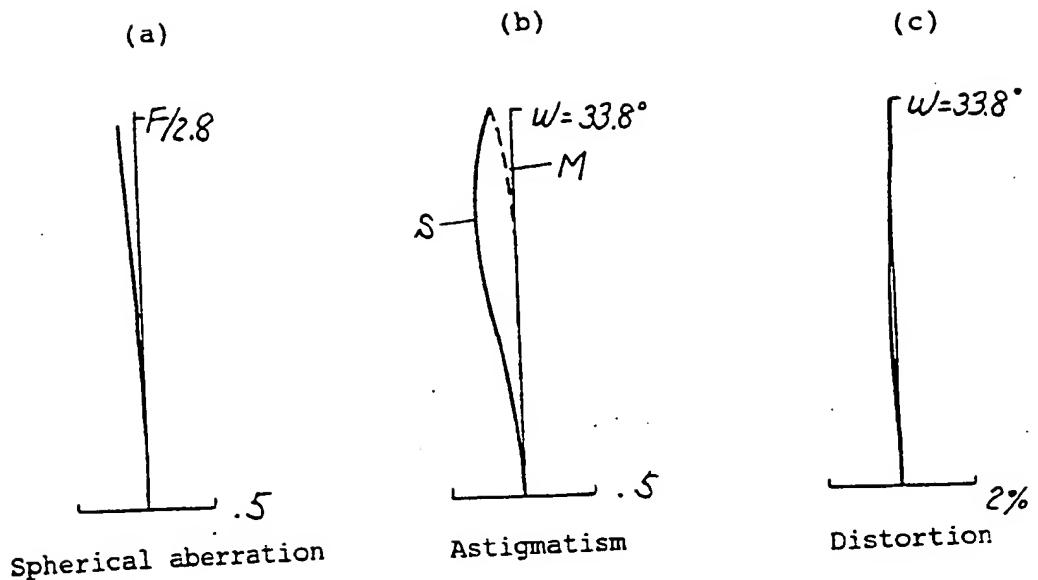


Fig. 4

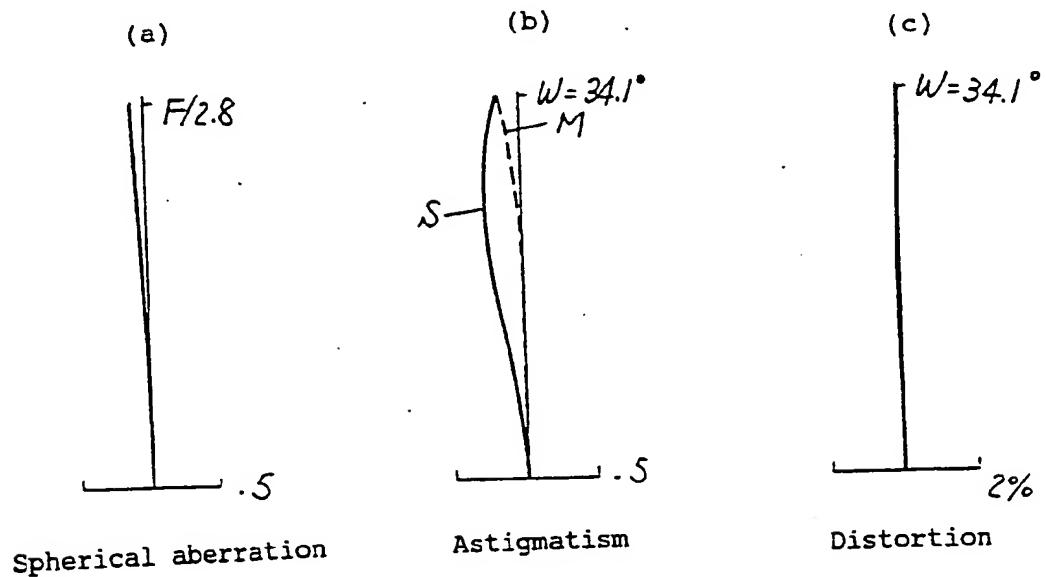


Fig. 5

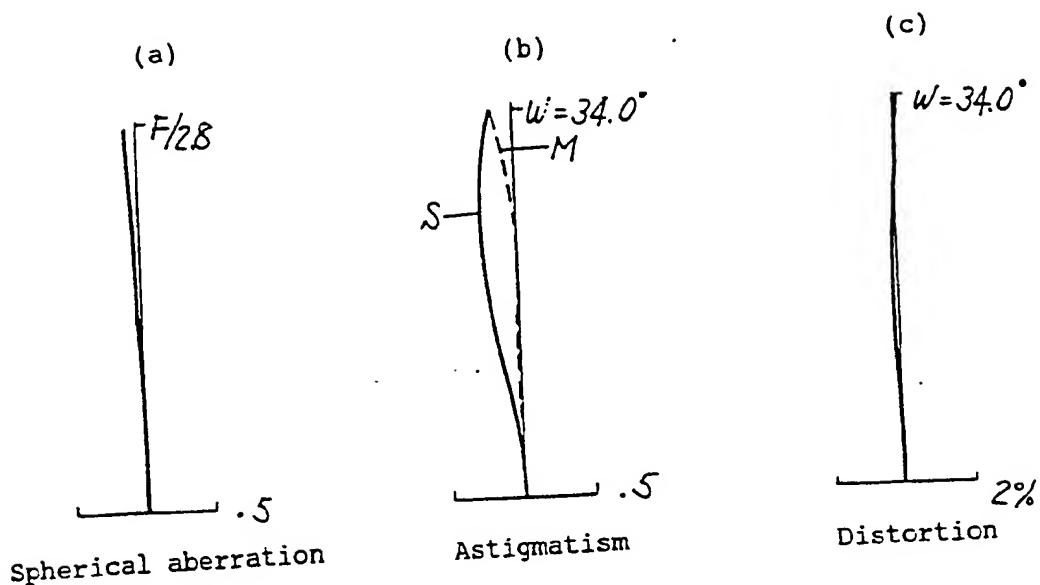


Fig. 6

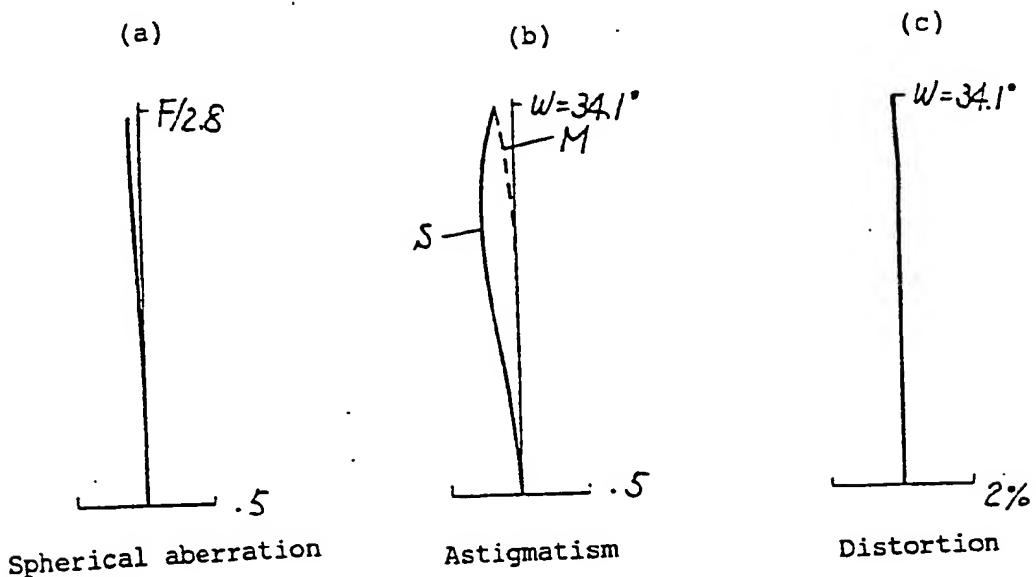


Fig. 7

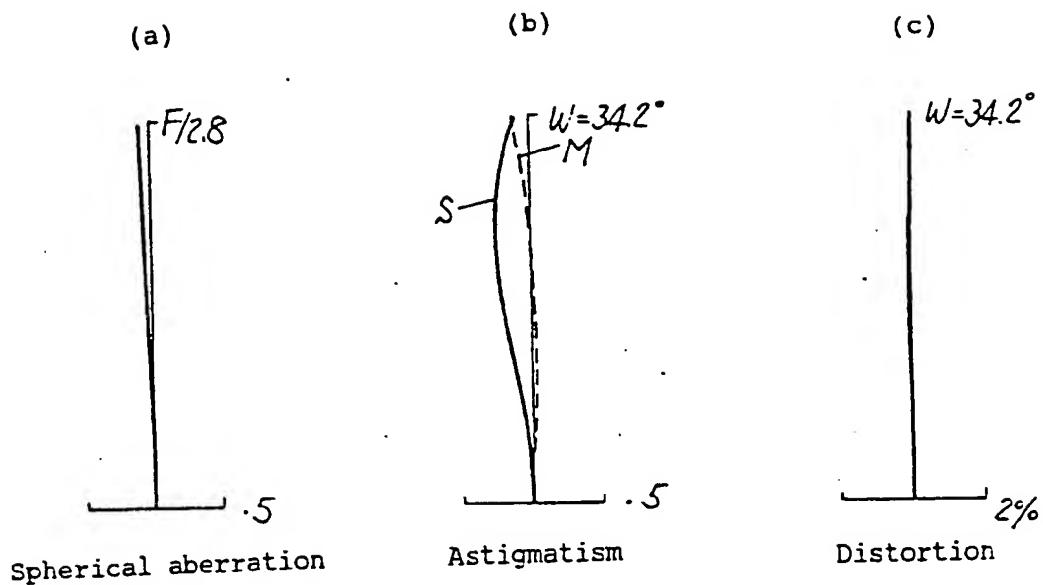


Fig. 8

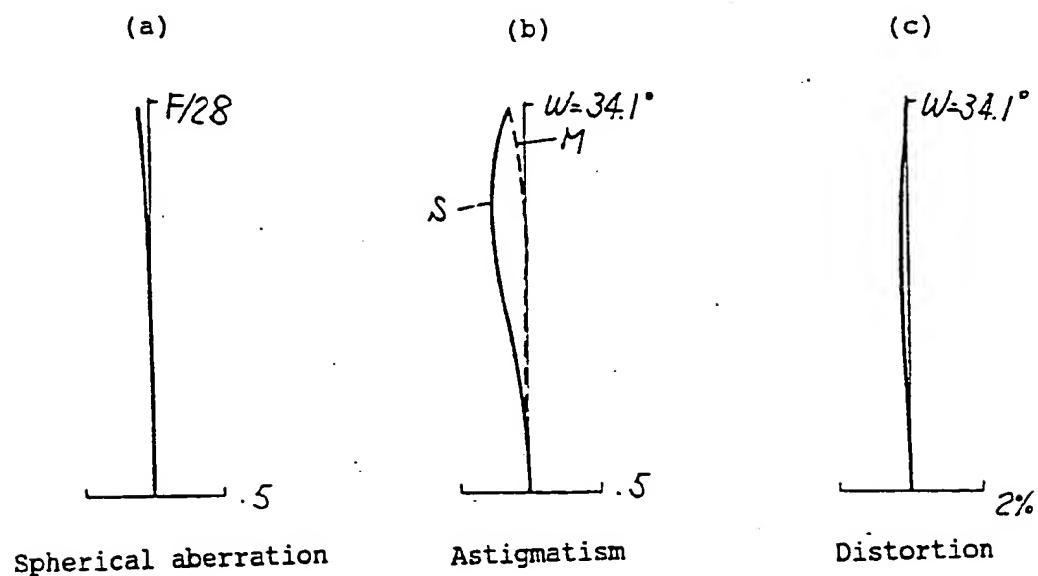


Fig. 9

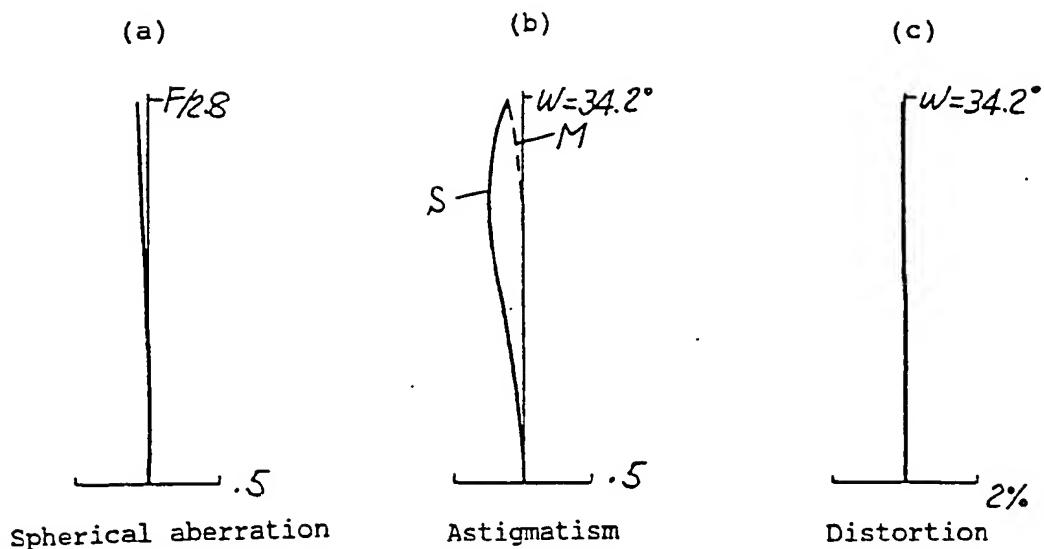


Fig. 10

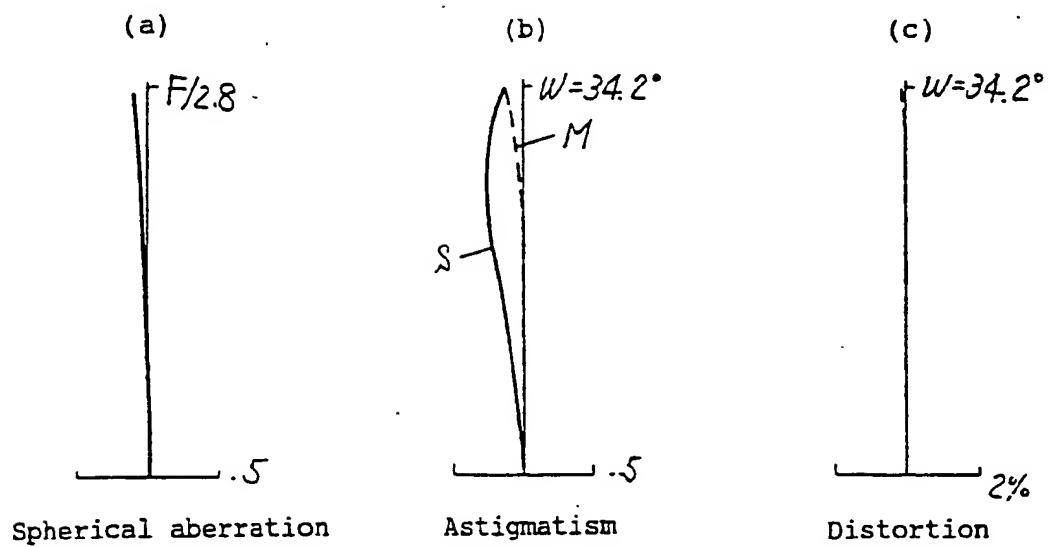


Fig. 11

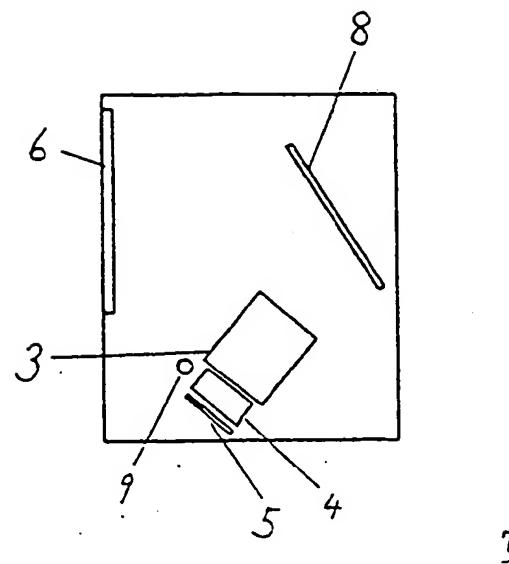


Fig. 12

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04.03.92 Bulletin 92/10

(54) Projection lens and projection television system using the same.

(57) A projection lens for projecting images displayed on an image display device having angle-of-view dependency has high image focusing characteristics corresponding to high definition images, wide field angle, and telecentric characteristics. In addition, a projection television system using the same can be minimized in its size.



European
Patent Office

EUROPEAN SEARCH
REPORT

Application Number

EP 90 30 2037

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	EP-A-0 083 090 (HUGHES AIRCRAFT CO) -----	17	G 02 B 13/16 G 02 B 13/18
A	EP-A-0 083 090 (* page 10, line 4 - line 34 *) * page 11, line 1 - line 27 *** figure 1 *** -----	1	G 02 B 13/22 G 02 B 13/04 H 04 N 9/31
X	US-A-4 464 018 (GAGNON) -----	17	
A	US-A-4 464 018 (* column 4, line 13 - line 68 *) * column 5 *** column 6, line 1 - line 7 *** figure ** -----	1	
A	US-A-2 600 805 (REISS) * the whole document ** -----	1,17	
A	US-A-3 947 094 (KEIJI IKEMORI) * the whole document ** -----	1,17	
A	US-A-4 759 619 (NAKAMURA ET AL) * column 4, line 67 - line 68 *** column 5, line 1 - line 28 *** figures 1,4,7 ** -----	1-3	
A	NHK LABORATORIES NOTE. no. 356, March 1988, TOKYO JP KANAZAWA ET AL: 'A 50-inch diagonal rear-projection display' * page 4, final paragraph *** page 5, paragraph 1 -paragraph 3 *** figures 2,3 ** -----	1,3,7	TECHNICAL FIELDS SEARCHED (Int. Cl.5)
A	US-A-4 722 593 (SHIMAZAKI) * column 2, line 60 - line 68 *** column 3 *** column 4, line 1 - line 57 *** figures 3,4 ** -----	1,3,7	G 02 B H 04 N
A	US-A-4 753 523 (HIROSE) * the whole document ** -----	1	
		-/-	
The present search report has been drawn up for all claims			

Place of search	Date of completion of search	Examiner
The Hague	08 January 92	WARD S.M.

CATEGORY OF CITED DOCUMENTS

- X : particularly relevant if taken alone
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REPORT

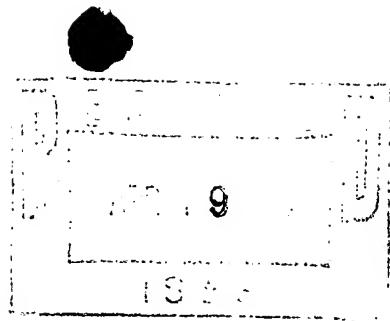
Application Number

EP 90 30 2037

DOCUMENTS CONSIDERED TO BE RELEVANT					
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)		
A	SOVIET INVENTIONS ILLUSTRATED ,Week 8646, Section P8, page 2, 24 December 1986, London UK & SU-A-1224771 (GOLO), 15 April 1986 "the whole document " -----	17			
TECHNICAL FIELDS SEARCHED (Int. Cl.5)					
The present search report has been drawn up for all claims					
Place of search	Date of completion of search	Examiner			
The Hague	08 January 92	WARD S.M.			
CATEGORY OF CITED DOCUMENTS X: particularly relevant if taken alone Y: particularly relevant if combined with another document of the same category A: technological background O: non-written disclosure P: intermediate document					
E: earlier patent document, but published on, or after the filing date D: document cited in the application L: document cited for other reasons 8: member of the same patent family, corresponding document					

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